No. 1764

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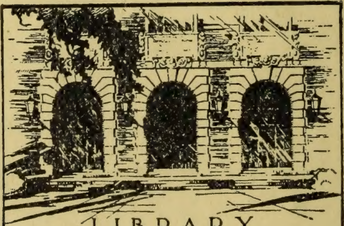
RULES.

No person shall be allowed to have out more than one volume at a time, which may be retained three weeks; and any person who shall retain a book from the Library beyond the time prescribed, shall pay to the Librarian a fine of ten cents for each week or a fraction of a week the Book is so kept; and if the Book is not returned at the end of six weeks from the time it was first taken out, the holder shall be liable to the Board for the retail price of the Book including the amount of fines imposed.

If any person shall lose or injure a Book he shall replace the same, or pay an equivalent in money, and if the Book lost or injured be one of a series, he shall make the series whole.

No person from whom any hire, fine or forfeiture is due, or who has damaged or lost any Book for which he has not paid, shall be permitted to have the use of the Library or Reading Room until satisfaction be made.

All Books shall be received of the Librarian and returned to him in person.



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REPORT

OF THE

SECRETARY OF WAR;

BEING PART OF

THE MESSAGE AND DOCUMENTS

COMMUNICATED TO THE

TWO HOUSES OF CONGRESS

AT THE

BEGINNING OF THE THIRD SESSION OF THE FORTY-SIXTH CONGRESS.

IN FOUR VOLUMES.

VOLUME III.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1880.

REPORT

OF THE

CHIEF OF ORDNANCE.

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REPORT

OF

THE CHIEF OF ORDNANCE.

WAR DEPARTMENT, ORDNANCE OFFICE,
Washington, October 1, 1880.

The Hon. SECRETARY OF WAR:

SIR: I have the honor to submit the following report of the principal operations of the Ordnance Department during the fiscal year ended June 30, 1880, with such remarks and recommendations as the interests of this branch of the military service seem to require.

The fiscal resources and expenditures of the department during the year were as follows, viz:

Amount in the Treasury to the credit of appropriations on June 30, 1879	$224,848 45
Amount in the Treasury not reported to the credit of appropriations on June 30, 1879	3,086 94
Amount in government depositories to the credit of disbursing officers and others on June 30, 1879	79,040 27
Amount of appropriations for the service of the fiscal year ended June 30, 1880	1,464,500 00
Amount refunded to ordnance appropriations in settling accounts during the fiscal year ended June 30, 1880	18,461 37
Gross amount received during the fiscal year ended June 30, 1880, from sales to officers; from rents; from collections from troops on account of losses of, or damage to, ordnance stores; from Chicago, Rock Island, and Pacific Railroad Company; from exchange of powder; from sales of condemned stores; and from all other sources not before mentioned	264,008 68
Total	2,053,945 71
Amount of expenditures during the fiscal year ended June 30, 1880, including expenses attending sales of condemned stores, exchange of powder, &c	$1,597,742 33
Amount deposited in Treasury during the fiscal year ended June 30, 1880, as proceeds of sales of government property	157,915 39
Amount lapsed into the Treasury from the appropriation "Ordnance material," under act of March 3, 1875, during the fiscal year ended June 30, 1880	75
Amount transferred from ordnance appropriations in settling accounts during the fiscal year ended June 30, 1880	52 36
Amount turned into the "surplus fund" on June 30, 1880	539 21
Amount in government depositories to the credit of disbursing officers and others on June 30, 1880	135,996 13
Amount in the Treasury not reported to the credit of appropriations on June 30, 1880	7,155 44
Amount in the Treasury to the credit of appropriations on June 30, 1880	154,544 10
Total	2,053,945 71

The duties and responsibilities of the Ordnance Department are fixed by the laws. The department provides arms and ordnance, and ordnance stores for our sea-coast defense, and the Regular Army in all its branches; supplies the whole body of the militia, the Marine Corps of the Navy, all other departments of the government when necessary to protect public money and property, and the thirty colleges authorized to receive arms. It does more, its province is to determine on the best, most efficient, and most effective war material for the service, and its responsibilities in this regard are ever present and never ending. The product that has taken years of study and trial to perfect not only in design, but in manufacture, may appear to the user so simple that the least imperfection will insure an adverse judgment. No one who has not had practical experience can understand or realize the many and complicated conditions that accompany the use of explosives, whether in the production of a heavy gun to pierce the thickest armor, or of the small metallic cartridge that has well nigh revolutionized modern methods of warfare. It is easier to criticise the completed product than it is to overcome the many difficulties and obstacles to the perfection of that product. I am proud to say that the Ordnance Department has enjoyed a large measure of success in the performance of its very varied and most important duties.

STATIONS AND DUTIES.

The officers of the department are stationed as follows: Two at the Ordnance Office; twenty-six at the Arsenals; five at the National Armory; two at the powder depots; three on the Ordnance Board; two at the foundries; three at the Agency and Proving ground; seven at the headquarters of Departments and Ordnance depots; four at the Military Academy; two on special service in the Interior Department; one in the Treasury Department, and two on sick leave.

During the fiscal year three officers of the line have been transferred to the department, after examination, as required by law.

Rock Island Arsenal.—The construction of workshops at the Rock Island Arsenal has been satisfactorily prosecuted under the skillful and economical management of Maj. D. W. Flagler, commanding, and liberal appropriations for that arsenal are recommended.

Benicia Arsenal.—I respectfully call attention to the necessity for a new machine shop at the Benicia Arsenal. The only manufacturing establishment on the Pacific Coast belonging to this department should be provided with every convenience and appliance necessary to place it on a working basis. That coast ought not to depend on the manufacturing facilities at arsenals three thousand miles distant, but should be in a manner self-sustaining.

Powder Depot.—During the past year a site for a powder depot was selected in Morris County, New Jersey, far removed from closely-settled neighborhoods, but convenient to railroad and canal transportation.

The site has been purchased and steps are being taken by Major Parker, commanding, to commence the erection of magazines, and continue the work as rapidly as means are provided by Congress. This depot, when storage room in sufficient quantity has been provided, will relieve the department from much anxiety and responsibility in regard to the storage and preservation of gunpowder. It will enable us to remove such a dangerous explosive from the vicinity of our cities, and, in preventing its deterioration, by storing in well-constructed magazines, repay the cost of its establishment before many years.

San Antonio Arsenal.—The report of a recent inspection of the San Antonio Arsenal, Texas, by one of our ordnance officers, fully justifies the estimates submitted for that arsenal. The additional land so often recommended should be purchased, new store-houses and quarters should be at once erected, and the old dilapidated buildings removed. In the long series of years during which that arsenal has so efficiently supplied the wants of the Rio Grande frontier, only ordinary and minor repairs have been made to the buildings, and the time has come when more substantial repairs and new constructions are an absolute necessity. We need shops and more storage room, and the appropriation of money estimated for is earnestly recommended.

Watervliet Arsenal.—At the Watervliet Arsenal all work has been conducted satisfactorily to the department. The high estimate placed by the Army and militia on the products made and issued at that arsenal are due to the great experience and able supervision of Col. P. V. Hagner, commanding.

Ordnance Depots.—The ordnance depots established at Fort Abraham Lincoln, Cheyenne, and Fort Leavenworth, and the San Antonio and Fort Union Arsenals, on the frontier, have been of the greatest convenience in speedily and thoroughly supplying the troops in the respective departments.

Frankford Arsenal.—Frankford Arsenal still continues to be the metallic cartridge factory, and its ammunition is without a superior, judging from Army reports. It has for some time been my intention to recommend the adoption of a reloading cartridge as an economy, and the trials and experiments conducted with that in view will soon enable me to reach a definite conclusion. The present long-range excitement points to heavy charges and severe recoils, but the experience of other armies and a little reflection convince me that for Army purposes the best average results can be obtained by keeping the charge within moderate limits.

Sandy Hook Proving Ground.—Estimates for buildings and improvements at the Sandy Hook Proving Ground have been submitted. The interesting, important, and successful labors that have been and are being conducted there fairly deserve the fostering care of Congress, and I recommend liberal appropriations for the proving ground.

UNITED STATES TESTING-MACHINE.

This extraordinary machine is now in successful operation at the Watertown Arsenal, under the command of Col. T. T. S. Laidley, Ordnance Department. The appropriation made last session for its care and operation will enable us to fully test its capabilities and make a substantial beginning toward the testing of metals.

This machine is considered the most perfect testing-machine in the world; equally able to test a single h r and the largest column; accurately testing specimens by either tension or compression with any load desired from 1 pound to 800,000 pounds, the specimens being of any length from one inch to thirty feet. Its determinations are of great value to the departments of the government and to the scientific and industrial interests of the whole country.

The memorial of the inventor of this machine, Mr. A. H. Emery, presented to Congress at the last session, asking for additional compensation and reimbursement, with a favorable report from the Committee on Claims of the House of Representatives, are herewith submitted. I respectfully recommend favorable action thereon.

MILITIA.

"Congress shall have power"—

> To provide for calling forth the militia to execute the laws of the Union, suppress insurrections, and repel invasions.
>
> To provide for organizing, arming, and disciplining the militia, and for governing such part of them as may be employed in the service of the United States, reserving to the States, respectively, the appointment of the officers, and the authority of training the militia according to the discipline prescribed by Congress.
>
> To make all laws which shall be necessary and proper for carrying into execution the foregoing powers, and all other powers vested by this Constitution in the Government of the United States, or in any department or officer thereof.
>
> No State shall, without the consent of Congress, * * * keep troops, or ships of war, in time of peace, * * * or engage in war, unless actually invaded, or in such imminent danger as will not admit of delay.

This is the language of the Constitution of the United States, and I invite attention to the completeness of the authority granted to Congress by these provisions.

In my last annual report this subject was discussed to a considerable extent, and some recommendations were made in the interest of a more efficient organization, a more complete armament and equipment, and a more thorough disciplining of the militia.

During the last session of Congress the Committee on the Militia of the House of Representatives, after mature consideration, reported a bill (H. R. 5638), accompanied by a report (No. 763), which I submit herewith.

That report gives an interesting history of the militia laws, from the first action of the Continental Congress in its series of resolutions of

July 18, 1775, and discusses in detail the proposed law which it now recommends. In its closing paragraphs the committee's report says:

While the proposed bill scarcely involves the

POWERS OF CONGRESS AND RIGHTS OF THE STATES,

your committee deem it proper to present its bearings on those points in order that no question may arise in regard to them.

There is no feature in our form of government in which the powers of the General Government and the rights of the States are so intimately interwoven as in the jurisdiction over the militia. One of the stated primary causes for forming the Union was to "provide for the common defense." In the opinion of the framers of the Constitution, a well-regulated militia was the essential means of providing for the common defense, and they accordingly framed the clause to provide that Congress shall have power—

"To provide for organizing, arming, and disciplining the militia, and for governing such part of them as may be employed in the service of the United States, reserving to the States respectively the appointment of the officers, and the authority of training the militia according to the discipline prescribed by Congress."

The purposes and provisions of this clause are clearly and distinctly stated and scarcely admit of misinterpretation. The States are expressly limited to the appointment of the officers and to training the militia, and in training it according to the discipline prescribed by Congress. If the power conveyed to Congress by the words "organizing, arming, and disciplining" could be doubted, the debates of the Federal Convention are sufficiently clear to remove them. The committee that reported the clause, on being asked the scope of the powers that they intended to convey, replied that they meant by "organizing," proportioning the officers to the men; by "arming," not only to provide for uniformity of arms, but the authority to regulate the modes of furnishing them, either by the militia themselves, the State governments, or the National Treasury; and by "disciplining," to prescribe the manual exercise, evolutions, &c., and that laws for disciplining must involve penalties and everything necessary for enforcing penalties.

The debates of the Federal Convention on adopting the clause, though short, are pertinent.

Mr. Mason, who introduced the subject, thought that all power over the militia should be vested in the General Government, which he subsequently modified by suggesting that this absolute power should be limited to a portion of the militia at a time, so that by serving in rotation the whole body would finally be disciplined.

Mr. Madison thought that the regulation of the militia naturally appertained to the authority charged with the public defense, that it did not seem in its nature divisible between two distinct authorities, and that the discipline of the militia is evidently a national concern, and ought to be provided for in the National Constitution.

The clause as reported by the committee had but little opposition, it being conceded, as stated by Mr. Randolph, that reserving to the States the appointment of the officers was all the security they needed. Mr. Dayton and Mr. Ellsworth expressed themselves in favor of placing greater limitation on the power of Congress, but a motion made for that purpose received only one vote, that of Mr. Ellsworth, who moved it, and the clause, as it now stands, was therefore adopted with a marked unanimity in sentiment and vote.

We have only adverted to the question of the constitutional power of Congress as a matter of historical interest in connection with the general subject, for whatever question there may be as to the constitutionality of the existing law, or of some of the plans heretofore suggested for reorganizing the militia, none can possibly arise on the proposed bill, for it is a happy solution of all the constitutional questions involved. There is not a compulsory feature in the bill. It simply says to the States that if they

will by their own laws provide for and enforce such requirements as Congress deems necessary to secure an efficient militia, Congress will exercise its unquestioned constitutional power, and provide for arming such militia out of the National Treasury.

Section 2 of the bill provides: "That the militia shall be divided into two classes; the active, to be known as the National Guard; and the inactive, to be known as the reserve militia."

Section 7 limits the number of the "active" militia to not more than seven hundred for each Representative or Delegate, that is an aggregate for the whole country of about 200,000 men, to be known as the National Guard. The "inactive" militia will be composed of the remainder of the "abled-bodied male citizens" between the ages of eighteen and forty-five, which amount to over 6,000,000 of men. It is thus seen that only one out of every thirty men will be enrolled in the National Guard, which is surely a very small fraction of the population for so large a country geographically as the United States.

The end and aim of this bill is to organize, arm and discipline only a small portion of the able-bodied-men, but to do so so perfectly that the country may at all times be in possession of 200,000 soldiers—citizen soldiers, as distinguished from the Regular Army—but soldiers in fact, in organization, in discipline, in the use of arms, and ready at a moment's call to take the field.

To do this thoroughly and effectually requires arms, clothing, equipage, time expended in camp, enthusiasm and encouragement from the top through all the grades to the private soldier at the bottom, but first of all a liberal appropriation by Congress to start and give a healthy impetus to the movement.

The object of this bill is simply stated by the committee in its report: "*That if they* (*the States*) *will by their laws provide for and enforce such requirements as Congress deems necessary to secure an efficient militia, Congress will exercise its unquestioned constitutional power, and provide for arming such militia out of the National Treasury.*" And with this in view its leading features are thus stated:

First. To substitute a volunteer militia, limited in number in time of peace, for the existing compulsory system that applies to the whole body of the people, and which has become so inapplicable as to be utterly disregarded.

Second. To make such provisions as will aid and encourage the formation of volunteer organizations, remove the disparity in their numbers and discipline that exists between different States, and promote their efficiency to a common standard that will make them available for all the purposes for which a militia is required.

Third. To abolish the present system of a permanent appropriation to provide arms and equipments for the militia, and substitute provisions prescribing with what arms and equipments the militia shall be furnished, and on what conditions—leaving it in the discretion of Congress to regulate the annual appropriations for that purpose.

Objection has been made to section 19 of this bill, empowering the President to order any part of the militia into the United States service, because it authorizes him in terms "To issue his orders for that purpose to such officers of the active militia as he may think proper."

As the committee's report very correctly states, this provision does "not differ materially from existing law." The act of February 28, 1795, "To provide for calling forth the militia," &c., authorizes the President "To issue his orders for that purpose to such officer or officers of the militia as he shall think proper," and section 1642, Revised Statutes, uses the same words; so that it would seem that this objection is raised in ignorance of the law passed eighty-five years ago, and which has remained unrepealed to this day.

While not claiming absolute perfection for its provisions, I am thoroughly convinced that such legislation will be timely and wise, show on the part of Congress an interest in this most important arm of the national power, convince those who have labored so faithfully to keep alive a healthy military spirit in the militia that their efforts have not been in vain, and will place the fighting portion of the country in a condition for prompt and efficient action.

This bill reaches in its effect every portion of the country, spreads the facilities for making good soldiers throughout the length and breadth of the land, neglects no portion, however remote or inaccessible, and supplies the means for training a nucleus of soldiers in every locality about which in time of need regiments and armies may rally. It will place the country in condition of active preparation for emergencies, and show to the world that the citizens of this country are its soldiers.

The general conclusions of the committee in its report are as follows:

> From this review of the subject your committee are satisfied that time has solved those difficulties of the militia system for which the wisdom of our predecessors could find no acceptable remedy, and that the great increase in the population of the country now makes it not only practicable but desirable to substitute the volunteer system for enforced militia duty in time of peace. The subject is one on which there never have been any political differences, and on which none should exist. Washington, as the exponent of the Federalists, was unceasing in his efforts to procure legislation, and Jefferson, as the leader of the Anti-Federalists, was even more importunate in urging it. In view of these facts, and of the fact that we now have practically no militia system, and that the strength and perpetuity of our republican form of government largely depend on the existence of a well-regulated militia, we indulge the hope that the subject will receive the earnest consideration which it deserves, and that some decisive action will be taken on it.

As bearing directly upon this subject, I submit copy of Senate Ex. Doc. 22, 45th Congress, 2d session, being my reply to the several points of inquiry embraced in Senate resolution of 13th of December, 1877, in regard to the militia.

For many years, in my Annual Reports and in other ways, I have urged upon Congress the wants of the whole body of the militia, and the necessity for legislation thereon. The permanent appropriation of $200,000, ample no doubt in 1808 for a population of eight millions, has proved entirely inadequate for a population of nearly fifty millions, and a country washed by two oceans, with over three thousand miles between their shores. The laws on our statute books for organizing the

militia are obsolete in part, and in part inoperative. They were probably found all-sufficient for the militia in the early portions of our history with a small population, the country sparsely settled, and no grand centers of busy, bustling, thriving people: but in our present condition, with an immense territory bordered by powerful neighbors, with immense wealth and the greatest prosperity, with a present and a future the envy and admiration of the nations, these laws are insufficient. They should be replaced by others that will more surely and practically carry out the views of the framers of the Constitution, and satisfy the present wants and future demands of our people.

The bill under consideration may not be complete in its provisions nor perfect in its details, nor sufficiently comprehensive in its scope, but it fixes our *active* volunteer militia within practicable limits, makes it an intelligent living force that can be utilized and controlled, and brings the protection of a legalized armed body of our citizens within easy reach of every portion of the country.

I have therefore the honor to recommend this subject to your favorable consideration, in the hope that the provisions of the bill will receive your approval, and that Congress will, at its next session, pass the bill, and make liberal appropriations to supply all the wants of the *active* militia.

TARGET PRACTICE—CREEDMOOR.

The interest manifested in rifle firing throughout the Army has culminated in the victory gained at Creedmoor by the Army team from the Division of the Missouri. In the international military match, September 16, 1880, the contest for the Hilton shield was narrowed down to the three Army teams, and to one each from New Jersey, Connecticut, and Pennsylvania. The Missouri team took the prize, the Atlantic and Pacific teams coming next in order. The scores were as follows: Missouri, 1,023; Atlantic, 1,014; Pacific, 1,004; New Jersey, 972; Connecticut, 959; Pennsylvania, 954.

The *Army and Navy Journal*, in its issue of September 25, 1880, page 149, speaking of last year's contest, says:

> It was now conceded that the rifles as well as the men had something to do in the victory of New York's marksmen, and during the winter of 1879-'80 the Ordnance Department, U. S. A., sought to perfect a rifle that, in the hands of a good team, should win. This, as the records of the match prove, they have most successfully accomplished, and the rifle used by the Army teams in 1880, with its six-groove barrel, special sights, increased ammunition, and perfect stock, is one of the handsomest weapons, military, that we have ever seen.

That the Army teams, and officers and soldiers individually, have done the service great honor at Creedmoor is conceded by all, but the Army should not, and will not, forget to give with lavish hand the fullest credit to those of the volunteers who established the firing ground at Creedmoor, and succeeded so well in satisfying the country of the crying necessity for the best marksmen among our people. These contests

will tend to draw closer the fraternal relations that should always exist between the volunteers and regulars, a bond of brotherhood that should be as intimate in peace as it must ever be in war, and this Department will in future, as it has in the past, assist the volunteer militia by every means in its power.

MILITARY EDUCATION AT COLLEGES.

Section 1225, Revised Statutes, as amended by act of July 5, 1876, authorizes the issue of arms, artillery, &c., to colleges where an officer of the Regular Army has been detailed, the number not to exceed thirty, &c. This law calls for material modifications. There should be more permanency in the detail and in the institution that is to receive these benefits.

As each State is expected to organize its portion of the National Guard, it should have also the educational facilities for the instruction of its young men in military art and science. To this end the law should increase the number of colleges entitled to receive arms, &c., allowing one college to each State to be selected by the legislature thereof, and an additional one or more for the larger States to be determined by the Secretary of War, the whole number not to exceed fifty. Service at a college should not be considered optional with the officer detailed, but be fixed as a military duty to which all officers are liable, only to terminate at the discretion of the War Department. Governmental supervision and inspection of these colleges as regards military training, discipline, and study, should be a condition attached to the acceptance of the liberality of the general government. The providing of officers and arms makes these colleges, in a sense, a very important portion of the military establishment, because of the direct influence they must exercise over the efficiency of the militia, supplying, as they will from year to year, a number of competent instructors.

ARMAMENT OF FORTIFICATIONS.

The appropriation for armament at the last session of four hundred thousand dollars is, I trust, an indication of a liberal policy on the part of Congress toward this indispensable arm of the national defense.

In making this appropriation Congress included in the item "the manufacture of four improved breech-loading twelve-inch rifled guns," and the debates clearly show that it was the intention that these four should be at once made. It as clearly appeared that the selection of the system was left to the Ordnance Department, under the Secretary of War, and the expectation was as plainly stated that the system used would be the one that had so successfully stood the test at the Sandy Hook proving ground.

The want of certain portions of plant to enable the foundries to undertake the manufacture of guns larger than any heretofore made in

this country, and the necessity that the department should supply a portion of it in aid of the enterprise, the long and tedious examinations and calculations to reach the exact cost that would pay the foundries a fair profit for their labor and risk, delayed the placing of contracts for some time. All this has, however, been satisfactorily settled, and the work will be pushed to completion as rapidly as possible.

No stronger argument in favor of large annual appropriations can be stated than the fact that the first of these four guns will be completed and delivered to us in sixteen months, the second in eighteen months, the third in twenty months, and the fourth in twenty-two months, or about two years after the passage of the bill making the appropriation.

The money that may be expected from year to year is so uncertain as to quantity that the foundries are not justified in running the risk of making such ample preparation of plant as the increased size of modern ordnance requires to insure a large yearly product. Two years to complete four guns is the very best that can be done by the foundries with all the assistance this department can render. May I not ask that it be recommended to Congress to increase the appropriation of last year, make it a permanent one, if possible, that the existing condition of things may be so far improved by Congressional encouragement as to enable our foundries to perfect their establishment so as to do the largest amount of work in the shortest possible time. Liberal appropriations for the armament of our forts are of the first importance, and cannot be too strongly urged.

In my last annual report reference was made to the trial of an 11-inch *muzzle-loading rifle* converted from a 15-inch smooth-bore, which had been fired only 33 rounds. The test for endurance of this gun was afterwards continued to a very successful conclusion; 401 rounds were fired, 27 being with 90 lbs. of powder and 495 lbs. shot; 174 with 90 lbs. of powder and 543 lbs. shot, and three with 95 lbs. powder and 540 lbs. shot (see report herewith). This trial affords additional evidence of the strength of this system of gun construction, which had been so successfully proven in the trial of the 8-inch rifles.

The 8-inch *breech-loading rifle*, which, at the date of my last annual report, had only been fired 202 rounds, has been further tested for endurance up to 501 rounds, 489 of which were with battering charges of 35 lbs. powder and 180 lbs. shot. The report of the Ordnance Board concludes as follows:

> The endurance of this system of gun construction, and the endurance as well as the successful manifestation of the breech mechanism, in the opinion of the Board, have been satisfactorily established, and, in its judgment, the department is warranted in their adoption for future new constructions, as well as in future conversions of smooth-bore into rifled guns.

I fully concur in the opinion of the Ordnance Board.

The chambered 8-inch rifle.—The decided advantages resulting from the use of chambers for heavy charges having been demonstrated by

testing a 3-inch rifle, it was decided to chamber one of the 8-inch rifles. The preliminary firings were so satisfactory that I directed the firing of 100 rounds with maximum charges of 55 lbs. powder and 180 lbs. of shot. The detailed report of the Ordnance Board is herewith submitted. Its conclusions are as follows:

This experiment shows that with pressures entirely within the limits of safety the increased velocity due to chambering has increased the power of the 8-inch rifle about one-third, and that the increase of power is accompanied by an increased accuracy of fire. The wear of bore incident to the higher charge with the 111 rounds fired seems no greater than that in the unchambered gun with the 35-pound charge.

The system of chambering in all future conversions or new constructions is recommended.

The battering charge of the ordinary 8-inch rifle is only 35 lbs. powder and 180 lbs. shot. By chambering, we are enabled to increase the powder charge from 35 to 55 lbs. Its penetration at 1,000 yards will be 9.93 inches, the ordinary rifle giving only 7.73 inches. The 9-inch English rifle gives 8.76 inches, so that by the use of the chamber the energy of the 8-inch has been increased beyond that of the next higher caliber, English—a most satisfactory result.

The report of the constructor of ordnance includes—

The report on a *breech-loading chambered field rifle* converted from a 3-inch wrought-iron gun gives the details of construction by which, at a reasonable cost, we are enabled to utilize the large number of muzzle-loading wrought-iron guns now on hand. The trial has been so conclusive that, with your approval, six of these guns are now being prepared for issue to the artilley for test in actual service.

The report on a *steel and iron field carriage* for the breech-loading rifle mentioned above gives the details of its construction. It is the intention to supply these carriages that they may be tested with the guns in the batteries of artillery. The introduction of metal carriages for the field service has not been a necessity until now, because of the large supply of those made of wood, but the advisability of substituting metal for wood was recognized in the experimental iron carriages made by Colonels Rodman and Benton fourteen years ago.

Among the papers submitted are:

The report of the construction of the 8-inch *chambered* rifle referred to heretofore;

Captain Smith's interesting progress report on *experimental cannon powders;* and Lieutenant Whipple's valuable report on *tests of bar iron* used in the fabrication of wrought-iron tubes for converted guns.

In closing this brief summary of the labors of the Ordnance Department on the great gun problem we can fairly lay claim to have achieved great success. As the use of gunpowder in full battering charges, continuously and thoroughly applied, is the only means that can be entirely relied upon as affording a sure and crucial test for endurance, it must be admitted that our system of conversion has, from actual experiments

on our proving-ground, proved a success for all calibers and kinds tested, and up to eleven inches in bore. We have therefore the strongest reasons to hope for equal success in the production of new guns of yet higher natures, made on the same general principles of construction—applicable alike to muzzle-loading and breech-loading systems—and this, too, while attaining all the advantages of the latest improvements in the more recent products of European nations.

It is but justice to give full credit, for what has thus far been so successfully accomplished, to Lieut. Col. S. Crispin, constructor of ordnance, and to the other members of the Ordnance Board, Lieut. Col. T. G. Baylor and Maj. C. Comly, and the late Lieutenant-Colonel Treadwell.

EXPERIMENTAL GUNS.

Under the act of Congress approved June 6, 1872, appropriating funds for the procurement and tests of experimental rifled ordnance of heavy calibers (to be selected by a board of officers of the United States Army to be appointed by the honorable Secretary of War) the department, under the authority of law, has procured, amongst others, several guns which are now on hand at the proving-ground at Sandy Hook awaiting trial. These guns are the Woodbridge 10-inch rifle, the Thompson 12-inch breech-loading rifle, the Sutcliffe 9-inch breech-loading rifle, the Lyman multi-charge gun, and the Mann 8-inch breech-loading rifle.

The Woodbridge gun has been fired 10 rounds; the Thompson 2 rounds; the Sutcliffe 26 rounds; the Mann 11 rounds, and the multi-charge gun 3 rounds.

As they were provided for experiments and tests, and none have so far been made to any extent, and, in view of the developments to be expected regarding the numerous questions involved in gun constructions, both muzzle-loading and breech-loading, and to be made in furtherance of the solution of the ballistic questions now occupying the attention of the military world, and the improvements to be developed in powders, projectiles, the system of rifling, etc., the trial of these guns, as contemplated by law, to fully test these different inventions, should be instituted by the department. I have accordingly estimated for $117,600, which, if appropriated, will enable me to have the merits of these different systems fully determined.

PROFESSIONAL PAPERS.

Attention is invited to the several interesting professional papers by officers of the Ordnance Department, herewith submitted. Among the most important are—

The report on the Gardner Machine Gun by the Ordnance Board, showing it to be one of simple construction, easily manipulated, and of sure action. A few have been procured for trial in the field.

Captain Greer's report on Colonel Benton's Electro-ballistic Machine for determining the velocity of projectiles.

Lieutenant Russell's report on Weldon's Range-finder.

Captain Smith's most valuable report on Rifled Guns, Howitzers, and Mortars made and used abroad, which includes an interesting discussion of the causes on which the effect of air spacing depends.

These several papers give an idea of the many fields of study which are presented to the ordnance officer, and the extent and manner in which some of these fields have been explored.

SMALL-ARMS.

There were manufactured at the National Armory, during the fiscal year, 20,387 rifles and carbines at a cost considerably less than that of previous years.

The operations at the armory have been conducted in the admirable and satisfactory manner which always characterizes the performance of every duty by Col. J. G. Benton, commanding. The reputation of the work there done has never stood higher than now, and it can safely rest on the deserved excellence of its arms, known and recognized everywhere.

On the 1st of July there were in store as a reserve supply, including the above number made, only 22,979, showing that the number on hand at the beginning of the year had been well-nigh exhausted during the twelve months, by issues to the Army and militia, &c. At this rate of manufacture and consumption, the day is far distant when our reserve supply of arms will have reached what all nations consider a proper one.

At its last session Congress made an appropriation of $300,000 for small-arms, being an increase of $50,000 over the appropriation for the year previous, and I indulge the hope that the amount will continue to be increased from year to year until the country is better prepared for any unforeseen exigency.

The Springfield rifle continues to give very general satisfaction, and the complaints made against it are not greater in number nor more intense than is the case in other armies the world over. I am satisfied that as a single breech-loader it has no superior as a military arm, and that it will not be superseded by anything short of a magazine gun. The latter will unquestionably be adopted, and we will as certainly do so, as not many years ago we adopted the revolver. No magazine gun has yet attained that perfection and completeness that will warrant its general introduction in the army. The Hotchkiss has met with reverses, due to hasty manufacture and imperfect design in some of its minor parts, which can hardly be charged to the invention. It is believed that these defects, in which the mechanical principles of the invention were not involved, have been corrected in the new model, and more favorable results may now be anticipated. The manufacturer's

experience with this gun proves that difficulties are ever to be met and overcome in perfecting a new invention that has to stand the severe test of field service. As a rule, a first-rate military arm must be of gradual growth; and be finally made up of successive improvements rendered necessary to correct defects developed in the hands of the soldier. The principle of the Hotchkiss is a good one, but there seems to be some prejudice existing in our service against the bolt system and its awkward handle that time and custom may overcome.

The calls for magazine guns by our cavalry, the improvements being made in these arms, and the necessity of extending the inquiry in order to get the best, induces me to recommend that an appropriation be made to enable this department to further study and test by actual trial in the field a few of the best magazine systems.

An appropriation of $500,000 for the manufacture of the Springfield gun during the next year is deemed a reasonable one. The strongest and most convincing argument for a continued peace is being thoroughly prepared for war. Our armories and arsenals fully stocked with war material, our fortresses well armed, and our militia well organized, armed, and equipped to march shoulder to shoulder with our small body of regulars, constitute the best peace offering we can present to the world. In the matter of preparation, economy during peace means extravagance in war, and, as a financial problem, the wise and timely expenditures of the present will be the truest economy.

RAMROD BAYONET.

On the 30th of January, 1878, I recommended to the honorable Secretary of War the abolition of the bayonet and saber. In my indorsement of May 3, 1879, on the report of the Equipment Board, I renewed that recommendation. Nothing has yet occurred to change my views expressed in these communications. While the General of the Army committed himself to no expression of opinion on the subject, his orders on the report of the Equipment Board included "the shaping and strengthening the present ram or cleaning rod to the uses of a bayonet or foil, after the manner of Lieutenant Zalinski, and the manufacture of a light but efficient knife or trowel for digging ground or other manifest uses."

Under instructions from this office Colonel Benton, commanding the National Armory, submitted a ramrod bayonet, being a simple modification of the one used in the Hall's breech-loading carbine nearly seventy years ago. It is strong and efficient, occupies the same place as the ordinary ramrod, and dispenses with the dangling bayonet scabbard. In the butt of the gun is a receptacle for the screw-driver, cartridge extractor and wiper. This arrangement reduces the weight carried by the soldier, and diminishes the expense to the United States. Having received the approval of the General of the Army and the sanction of the Secretary of War, one thousand are being prepared to be sent into the field for trial. It is the first step toward the abolition of the

bayonet, and its simplicity, compactness, and lightness will, I am sure, commend it to the favor of the soldier. For hundreds of years the war between gunpowder and steel has been going on, with the advantage and gain always in favor of the former, and the saber and bayonet must in their turn take their places in our museums by the side of the old pike and the cuirass. They must yield to the revolver and the rifle—cold steel to gunpowder and lead.

Carrying out the order of the General of the Army, I submitted a knife which received his approval and your sanction, and one thousand have been ordered made to be issued with the arms provided with the ramrod-bayonet.

EXTREME RANGES.

The reports on "Extreme Ranges of Military Small-Arms," by Colonel Benton and Capt. John E. Greer, Ordnance Department, are herewith submitted. These trials were undertaken and prosecuted under instructions from this office, and the work has been performed with a great degree of thoroughness and completness. These reports will amply repay careful perusal by those in the Army and out of it who are interested in rifle firing, and it is thought that much of the data given will be found new and useful. The use of the telephone in determining the time of flight of projectiles, especially at very long ranges, was first made at the Sandy Hook Proving Ground, and its application in these experiments was found most valuable and important. Among Captain Greer's conclusions are the following :

As a result of these trials it will be seen that the service rifle with service cartridge is amply sufficient to disable and possibly to kill up to nearly 3,000 yards; that the same is true of the carbine using the rifle cartridge; that the 500-grain bullet fired from any rifle with a twist sufficient to give the necessary rotation will range nearly 3,700 yards; that variations in weight of powder charge within ordinary limits have no effect on elevation at extreme ranges, velocities approximating to each other; and finally, that with a cartridge prepared as at present, but with an increased weight of ball, the service rifle may be made, if desired, as long a ranging arm as any known.

LIFE-SAVING SERVICE.

Lieut. D. A. Lyle, Ordnance Department, is still on duty under the Secretary of the Treasury, and his report "On Foreign Life-saving Rockets and Rocket Apparatus" is herewith submitted. This report including descriptions of, and results of trials with, the Russian, German, and English apparatus, is a valuable addition to our knowledge of this important service, and reflects credit on the ability and labors of this excellent officer.

GEOLOGICAL SURVEY.

In April last I had the honor to submit to the honorable Secretary of War the report of Captain Dutton, Ordnance Department, "Of explorations and studies in Utah Territory, prosecuted during the years

1875, 1876, and 1877, in connection with the survey of Maj. J. W. Powell, under the Interior Department." This report was transmitted to the Secretary of the Interior and published in a quarto volume, entitled "Report on the geology of the high plateaus of Utah."

Major Powell, the director of the survey, in his prefatory note, pays this well-merited compliment to Captain Dutton: "With great labor and skill the work has been accomplished, and its results are presented in this volume, which will be found to extend our knowledge of the geology of the United States, and to be an important contribution to geologic philosophy."

Under authority of law, Captain Dutton was continued on the geological survey, and is at present in the field.

CLERICAL FORCE.

The clerical force was increased at the last session of Congress by the addition of ten enlisted men. With the number thus increased, the current duties of this office, and the work that has accumulated for years, can be properly performed. There is no doubt that the grades should be changed and that three clerks of class four should be allowed to take charge of the three important divisions of this bureau.

I have the honor to submit the following papers, heretofore referred to:

Appendix 1.—Statement of principal articles procured by purchase and fabrication at the Arsenals during the year ended June 30, 1880.

Appendix 2.—Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the year ended June 30, 1880.

Appendix 3.—Apportionment for the fiscal year ended June 30, 1880, of the annual appropriation of $200,000 for arming and equipping the militia, under sections 1661 and 1667 Revised Statutes.

Appendix 4.—Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1879, to June 30, 1880, under section 1667 Revised Statutes.

Appendix 5.—Statement of ordnance, ordnance stores, &c., distributed to colleges from July 1, 1879, to June 30, 1880, under section 1225 Revised Statutes.

Appendix 6.—Statement of arms, ammunition, &c., distributed to the Territories and States bordering thereon from July 1, 1879, to June 30, 1880, under the joint resolutions of July 3, 1876, March 3, 1877, March 9 and June 7, 1878.

Appendix 7.—Statement of arms and ammunitions issued to the executive departments under the provisions of the act of March 3, 1880.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

Lieut. Col. S. Crispin, Ordnance Department.

Appendix 8.—Construction of a 3.17-inch muzzle-loading rifle.

Appendix 8[a].—Construction of an 3.18-inch breech-loading chambered rifle.

Appendix 8[b].—Construction of an iron field carriage for a 3.18-inch breech-loading rifle.

Appendix 8[c].—Construction of an 8-inch muzzle-loading rifle (converted) with an increased pitch of rifling.

Appendix 8[d].—Construction of an 8-inch muzzle-loading chambered rifle (converted).

Appendix 8[e].—Progress report on experimental cannon powders.

Appendix 8[f].—Tests of bar iron used in the fabrication of wrought-iron tubes for converted rifles.

REPORTS OF THE ORDNANCE BOARD.

Lieut. Cols. S. Crispin and T. G. Baylor and Maj. C. Comly, Ordnance Department.

Appendix 9.—Field, siege, and sea-coast artillery.

Appendix 9[a].—Rifled and spherical projectiles.

Appendix 9[b].—Report on 11-inch muzzle-loading rifle, No. 1.

Appendix 9[c].—Report on 8-inch breech-loading rifle, No. 1.

Appendix 9[d].—Report on 8-inch muzzle-loading chambered rifle, No. 28.

Appendix 9[e].—Report on 3.18-inch breech-loading chambered rifle, No. 774.

Appendix 9[f].—Report on powders for 4.5-inch siege rifles.

MISCELLANEOUS.

Appendix 10.—Annual report of the principal operations at the Rock Island Arsenal, 1880, *Maj. D. W. Flagler*, Ordnance Department, commanding.

Appendix 11.—Description of a machine for printing paper targets, and a barrack gun rack, devised by *Maj. D. W. Flagler*, Ordnance Department.

Appendix 12.—Report on a new cartridge annealing furnace, by *Lieut. Col. J. M. Whittemore*, Ordnance Department.

Appendix 13.—Description of an arm-rack for company quarters, by *Capt. F. H. Phipps*, Ordnance Department.

Appendix 14.—Report on foreign life-saving apparatus, by *Lieut. D. A. Lyle*, Ordnance Department.

Appendix 15.—Description of a new method of fastening faking boxes for the life-saving service, by *Lieut. D. A. Lyle*, Ordnance Department.

Appendix 16.—Descriptive report on two galvanized sheet-iron faking

boxes designed for the life-saving service, by *Lieut. D. A. Lyle*, Ordnance Department.

Appendix 17.—On the U. S. testing machine.

Appendix 18.—On the militia.

Appendix 19.—Trial of the Gardner machine gun.

Appendix 20.—Gallery target practice.

Appendix 21.—Benton's electro-ballistic machine for determining the velocity of projectiles.

Appendix 22.—Carriage for the Lowell battery gun, by *Col. P. V. Hagner*, Ordnance Department.

Appendix 23.—Report on the Welden range finder, by *Lieut. A. H. Russell*, Ordnance Department.

Appendix 24.—Instructions for the care and use of cartridge reloading tools, by *Lieut. Col. J. M. Whittemore*, Ordnance Department.

Appendix 25.—Extreme ranges of military small-arms, by *Col. J. G. Benton* and *Capt. John E. Greer*, Ordnance Department.

Appendix 26.—The most powerful rifled guns, howitzers, and mortars existing in 1880, by *Capt. Charles S. Smith*, Ordnance Department.

Appendix 27.—Showing stations and duties of the officers of the Ordnance Department on the 1st of October, 1880.

I have the honor to be, very respectfully, your obedient servant,

S. V. BENÉT.

Brigadier-General, Chief of Ordnance.

APPENDIX 1.

Statement of principal articles procured by fabrication at the arsenals and by purchase during the year ended June 30, 1880.

Class I.

15 Gatling guns, caliber .45, 10 barrels, long.
5 Hotchkiss breech-loading mountain guns, caliber 1.65 inches.
1 breech-loading chambered wrought-iron rifle, caliber 3.20 inches.

Class II.

2 carriages and limbers for Hotchkiss revolving guns, caliber 1.5 inches.
5 carriages for Hotchkiss mountain guns, caliber 1.65 inches.
1 iron carriage for breech-loading rifle, caliber 3.20 inches.
1 carriage and limber for Gatling gun, caliber .45.
10 carriages and limbers for Lowell battery guns, caliber .45.
3 gun carriages for Life-Saving Service.
25 Laidley cavalry forges.

Class III.

100 ammunition boxes for Lowell battery guns.
50 feed cases for Gatling guns.
5,000 feed cases for Lowell battery guns.
45 gun covers, various.
52 handspikes, various.
165 harness bags.
5 sets harness for Hotchkiss mountain guns.
402 Coston's pouches for Life-Saving Service.
212 paulins, 12 by 15 feet.
100 paulins, 8 by 10 feet.
200 securing stakes.
3 pack saddles for Hotchkiss mountain carriages.
18 sponge covers, various.
46 sponges and rammers, various.
40 tube pouches.
118 vent covers.
36 vent pieces.
50 wipers for mortars.

Classes IV and V.

3,000 1.5-inch Hotchkiss shells.
4,200 1.65-inch Hotchkiss shells.
20 2.9-inch experimental shot, Butler's.
50 3-inch Butler case shot.
180 3-inch Butler shells.
1,005 3-inch Sawyer canister.
25 3.18-inch experimental shot.

25 3.18-inch experimental shells.
245 3.15-inch experimental Butler shot.
50 3.18-inch Hotchkiss shells.
100 3-inch shot, Mann's.
10 3-inch shot, Sibley.
1,285 8-inch Butler shot.
25 8-inch Dana shot.
20 8-inch Reilly shot.
5 8-inch Varney shot.
15 8-inch Butler shells, Navy.
5 8-inch Butler shells.
125 11-inch Butler shot.
40 8-inch mortar shells.

CLASS VI.

1 Hotchkiss magazine carbine, caliber .45.
5,385 Springfield carbines, caliber .45.
13 Hotchkiss magazine rifles, caliber .45.
1,500 Hotchkiss magazine Navy rifles, caliber 45.
14,502 Springfield rifles, caliber .45.
500 Springfield cadet-rifles, caliber .45.
2,000 Colt's revolvers, caliber .45.
14 cadet swords.
103 sabers for cavalry and field officers.
5 officers' swords.
3 soldiers' knives.

CLASS VII.

10,200 curry combs.
10,000 horse brushes.
8,000 saddle blankets.
1,018 felt saddle-cloths.
7,000 meat cans.
4,005 tin cups.
4,562 hair cinchas.
7,848 sets knives, forks, and spoons.
56,818 appendages for small-arms.

CLASS VIII.

46,783 cartridge bags, filled.
1,209,780 carbine ball cartridges, caliber .45.
1,925,000 rifle ball cartridges, caliber .50.
3,875,947 rifle ball cartridges, caliber .45.
21,000 rifle blank cartridges, caliber .58.
375,140 rifle blank cartridges, caliber .45.
5,400 blank cartridges for Gatling gun, caliber .45.
44,400 revolver ball cartridges, caliber .50.
100,228 revolver ball cartridges, caliber .45.
490 revolver blank cartridges, caliber .45.
3,500,300 lead balls, caliber .45.
500 explosive bullets.
82,700 pounds hexagonal powder.
13,262 pounds musket powder.
2,350 pounds English pebble powder.

1,800 pounds cannon powder.
273,160 friction primers.
4,170 electric cannon primers.
5,630,000 small-arm cartridge primers.
201,800 powder charges.
250 Hotchkiss percussion fuses.
2,000 fuses, various.

CLASS IX.

230 blocks, various.
118 chocks, various.
2 Laidley gun lifts.
1 hand cart.
9 handspikes, maneuvering.
1 lifting jack.
89 rollers, various.
38 shifting planks.
13 platforms for mortars.
10 platforms for siege carriages.
68 Laidley revolving targets.
16 cast iron targets.

CLASS X.

535 sabots, various.
330 tin straps.
116,114 spare parts for small-arms.
41,976 parts of infantry equipments.
685 parts of cavalry accouterments.
44,537 parts of horse equipments.
571 parts of artillery carriages, various.
73,000 cartridge shells, caliber .45.
49,835 cartridge bags, empty, various.

MISCELLANEOUS.

1,164 arm chests.
9,799 boxes, packing, wood.
4,212 tin cans.
96 packing cases, Madigan's.
10 sets packing cases, Evan's.
2 bullet-pressing machines.
3 cartridge crimping and tapering machines.
1 cartridge-gauging machine.
1 cartridge-heading machine.
3 bullet-lubricating machines.
1 cartridge-weighing machine.
1 rolling machine.
1 star gauge ring and points.
213 sets reloading tools for small-arm cartridges.
74 cast-iron heating stoves for quartermaster's department.
526 boxes leather blacking.
69,825 pounds barrel molds.
395,626 pounds gun steel.
157,155 pounds sheet copper.
707,847 pounds iron beams.
30,957 pounds leather.

4,119 sides leather.
259 gallons lacquer.
8,198 pounds harness oil.
664 gallons coal oil.
378 gallons cosmoline oil.
199 gallons engine oil.
2,351 gallons lard oil.
5,211 gallons linseed oil.
827 gallons neatsfoot oil.
3,240 gallons sperm oil.
19,528 pounds paint.
37,458 pounds rope, twine, and thread.
26,292 pounds white lead.
19,385 bushels coal.
2,598 tons coal.
7,112 tools and utensils.

APPENDIX 2.

Statement of ordnance, ordnance stores, &c., issued to the military establishment, exclusive of the militia, during the fiscal year ended June 30, 1880.

CLASS I.

7 Gatling guns, caliber .45, 10 long barrels.
2 Gatling guns, caliber .45, 10 short barrels.
2 Hotchkiss revolving cannon, caliber 1.5.
8 Hotchkiss mountain guns, caliber 1.65.
10 3-inch rifled guns.
1 3.5-inch Blakely guns.
6 4.5-inch siege guns.
5 6-pounder bronze guns.
6 light 12-pounder bronze guns.
6 12-pounder mountain howitzers.
6 20-pounder Parrott guns.
2 30-pounder Parrott guns.
51 8-inch rifled guns.
6 8-inch siege mortars.

CLASS II.

2 beds and frames for short-barrel Gatling guns.
4 tripods for short-barrel Gatling gun.
2 Gatling gun carts.
1 Gatling battery cart.
7 carriages and limbers for long-barrel Gatling gun, caliber .45.
2 carriages and limbers for Hotchkiss revolving cannon, caliber 1.5 inch.
8 carriages for Hotchkiss mountain guns, caliber 1.65 inch.
13 carriages and limbers for 3-inch rifles.
4 3-inch caissons and limbers.
5 6-pounder carriages and limbers.
4 6-pounder carriages without limbers.
9 12-pounder carriages and limbers.
1 12-pounder carriage without limber.
4 12-pounder caissons and limbers.
2 12-pounder mountain howitzer carriages.
6 12-pounder prairie carriages and limbers.
4 4.5-inch siege carriages and limbers.
2 30-pounder Parrott carriages and limbers.
51 8-inch casemate carriages and chassis.
1 15-inch Rodman carriage and chassis.
1 20-inch Rodman carriage and chassis.
1 24-pounder mortar bed.
6 8-inch siege mortar beds.
2 10-inch siege mortar beds.
13 Laidley cavalry forges.
4 portable cavalry forges.
1 traveling forge "A" and limber.
1 battery wagon "C" and limber.
1 limber for traveling forge.

CLASS III.

180 harness bags.
102 rear eccentric axle bars.
51 long friction clamp bars.
51 short friction clamp bars.
5 elevating bars.
102 maneuvering bars.
6 pinch bars.
2 budge barrels.
6 baskets for mortar implements.
23 fuse blocks.
2 pass boxes.
2 iron forge buckets.
1 wooden forge bucket.
28 iron sponge buckets.
8 wooden sponge buckets.
39 iron tar buckets.
35 gutta-percha water buckets.
8 iron water buckets.
26 leather water buckets.
10 papier-maché water buckets.
10 watering buckets.
2 gunners' calipers.
13 pointing cords.
30 fuse cutters.
13 fuse extractors.
3 copper powder funnels.
156 gunners' gimlets, field.
4 gunners' gimlets, siege.
5 fuse gouges.
29 maneuvering handspikes, wood.
13 shod handspikes.
47 trail handspikes.
12 trail handspikes for Gatling carriage.
5 trail handspikes for prairie carriage.
84 sets harness for 2 lead horses.
73 sets harness for 2 wheel horses.
2 sets draught harness for mountain howitzer carriage.
7 sets harness, 1 horse, for Hotchkiss mountain gun.
6 sets harness, 2 horses, for Laidley forge.
1 set harness, 2 horses, for Gatling cart.
69 gunners' haversacks.
7 pendulum hausses, 6-pounder.
9 pendulum hausses, 3-inch.
9 pendulum hausses, 12-pounder.
2 pendulum hausses, mountain howitzer.
1 shell hook.
13 tow hooks.
5 ladles and staves.
2 common lanterns.
3 dark lanterns.
12 globe lanterns.
3 magazine lanterns.
122 lanyards for friction primers.
5 mauls.

15 powder measures.
33 paulins, 5 by 5 feet.
17 paulins, 6 by 10 feet.
4 paulins, 10 by 10 feet.
151 paulins, 12 by 15 feet.
65 gunners' pincers.
9 plummets.
4 gunners' pouches.
28 pendulum hausse pouches.
6 sight pouches.
88 tube pouches.
24 prolonges.
3 gunners' quadrants, brass.
2 rammers and staves, 4.5-inch.
3 rammers and staves, 8-inch.
1 fuse saw.
5 pack saddles and bridles.
2 tangent scales.
3 scrapers for cannon.
12 scrapers for shot.
2 pendulum hausse seats.
1 quadrant seat, Zalinski's.
1 trunnion sight seat.
1 sight, Quinan, modified.
4 breech sights, 4.5-inch.
5 front sights, 3-inch.
2 front sights, 4.5-inch.
3 front sights, mountain howitzer.
2 gunners' sleeves.
6 cannon spikes.
33 sponge covers, 6-pounder.
11 sponge covers, 3-inch.
2 sponge covers, 4.5-inch.
43 sponge covers, 12-pounder.
11 sponge covers, 12-pounder mountain howitzer.
4 sponge covers, 30-pounder.
1 sponge and rammer, Hotchkiss mountain gun.
31 sponges and rammers, 6-pounder.
47 sponges and rammers, 3-inch.
2 sponges and rammers, 4.5-inch.
59 sponges and rammers, 12-pounder.
3 sponges and rammers, field howitzer.
27 sponges and rammers, mountain howitzer.
1 sponge and staff, 3-inch.
4 sponges and staves, 12-pounder.
2 sponges and staves, 8-inch.
8 pointing stakes.
200 securing stakes.
71 thumb-stalls.
7 tompions, 6-pounder.
14 tompions, 3-inch.
8 tompions, 4.5-inch.
10 tompions, 12-pounder.
1 tompion, 12-pounder mountain howitzer.
2 tompions, 20-pounder.
1 tompion, 30-pounder.

4 tompions, 8-inch mortar.
13 tompions, 10-inch.
9 tompions, 15-inch.
284 vent covers.
36 vent pieces.
43 vent punches, field.
50 wipers for mortar.
216 priming wires, field.
24 priming wires, siege.
20 worms and staves, field.
1 worm and staff, siege.
23 fuse wrenches.

Implements for long-barrel Gatling gun, caliber .45.

350 feed cases.
7 clamps for worm gear.
15 gun covers.
7 drifts.
7 shell drivers.
10 headless shell extractors.
6 oscillators.
7 brass wiping rods.
7 lock screw drivers.
7 small screw drivers.
7 T screw drivers.
4 peep sights.
7 adjusting screw wrenches.
3 pin wrenches.
7 rear guide nut wrenches.

Implements for short-barrel Gatling gun, caliber .45.

204 feed cases.
2 clamps for worm gear.
3 gun covers.
3 shell drivers.
2 oscillators.
2 brass wiping rods.
2 lock screw drivers.
3 small screw drivers.
2 T. screw drivers.
2 adjusting screw wrenches.
1 elevating screw wrench.
2 pin wrenches.
2 rear guide nut wrenches.
5 gun covers, Gatling gun, caliber .50.
3 gun covers, Gatling gun, caliber 1 inch.

Implements for Hotchkiss revolving gun.

2 sets accessories, feed cases, &c.
2 gun covers.
4 wiping rods.
2 peep sights.
7 sets implements for Hotchkiss mountain gun.
4 gun covers for Hotchkiss mountain gun.

Classes IV and V.

1,543 1.5-inch Hotchkiss projectiles.
3,210 1.65-inch Hotchkiss projectiles.
108 2.9-inch Parrott canister.
250 3-inch shot.
657 3-inch shell.
630 3-inch case.
30 3-inch canister.
268 12-pounder howitzer shell.
316 12-pounder case.
264 12-pounder canister.
202 4.5-inch shot.
375 4.5-inch shell.
200 30-pounder shot.
250 30-pounder shell.
200 100-pounder shot.
100 100-pounder shell.
10 200-pounder shot.
60 200-pounder shell.
1,400 8-inch shot.
580 8-inch shell.
297 10-inch shell.
100 13-inch shell.
210 15-inch shell.

Class VI.

302 Hotchkiss magazine carbines, caliber .45.
6,670 Springfield carbines.
300 Hotchkiss magazine rifles, caliber .45.
16,367 Springfield rifles.
35 Springfield rifles, officers' model.
100 Springfield rifles, caliber .50.
6 rifle muskets, caliber .58.
1,185 Colt's revolvers, caliber .45.
4 Colt's revolvers, caliber .44.
332 Schofield's Smith and Wesson revolvers, caliber .45.
19 double barrel breech loading shot guns.
112 artillery sabers.
489 cavalry sabers.
50 officers' sabers.
14 cadet swords.
132 musicians' swords.
56 non-commissioned officers' swords.
5 officers' swords.
296 trowel bayonets.

Class VII.

108 artillery saber belts.
61 artillery saber belt plates.
88 carbine cartridge boxes.
1,635 carbine cartridge pouches.
2,447 carbine slings.
2,219 carbine sling swivels.

1,222 pistol cartridge pouches.
2,560 pistol holsters.
1,867 cavalry saber belts.
1,897 cavalry saber belt plates.
138 saber knots.
35 brace yokes and stay straps.
2,377 steel bayonet scabbards, Hoffman's attachment.
1,208 steel bayonet scabbards and frogs, hook attachment.
662 trowel bayonet scabbards.
13,697 canteens and straps.
1,828 carrying braces.
120 shoulder braces.
7,030 cartridge belts.
49 shoulder belts and plates for bayonet scabbard.
4,910 cartridge boxes, McKeever's.
100 cartridge boxes, No. 1.
51 cartridge boxes, No. 2.
1,469 cartridge loops.
4,310 clothing bags and straps.
5,238 coat and blanket straps.
304 bayonet scabbard frogs, hook attachment.
184 sliding frogs.
7,859 forks.
6,541 gun slings.
8,757 haversacks and straps.
8,090 knives.
7,763 meat cans.
363 intrenching tool scabbards.
190 sheaths for knife.
7,798 spoons.
4 non-commissioned officers' swords, belts, and plates.
327 pairs stay or steady straps.
50 musicians' waist belts and plates.
7,369 tin cups.
138 con-commissioned officers' waist belts and plates.
2 non-commissioned officers' waist belt plates.
3,075 privates' waist belts.
2,926 privates' waist belt plates.
115 valises.
64 valise straps.
19 extractors and recappers.
19,843 headless shell extractors.
11 ball molds (2 balls), pistol.
2 ball molds (4 balls), rifle.
3,816 tumbler punches.
7,314 jointed ramrods, steel.
346 wiping rods, pistol.
580 wiping rods, wood.
14,566 screw drivers.
4,518 combination screw drivers.
2 clamp screw drivers.
1,151 pistol screw drivers.
861 spring vises.
768 brush wipers and thongs.
940 blanket bags.
2,817 curb bridles.

1,383 watering bridles.
391 cruppers.
6,295 curry combs.
1,405 hair cinchas.
279 leather girths.
1,356 linen girths.
7,933 halters and straps.
10,412 horse brushes.
2,361 horse covers.
8,137 lariats.
1,617 links.
6,985 nose bags.
3,009 picket pins.
1,398 saddles.
4,617 saddlebags.
487 artillery saddle blankets.
5,787 cavalry saddle blankets.
887 saddle cloths.
4,254 side lines.
435 forage sacks.
873 carbine sockets.
4,653 spurs.
5,361 spur straps.
1,851 stirrups.
2,681 stirrup straps.
23 stirrups with guidon sockets.
2,892 surcingles.

CLASS VIII.

SMALL-ARM AMMUNITION.

1,500 Gatling ball cartridges, caliber 1 inch.
5,000 Gatling blank cartridges.
5,000 carbine ball cartridges, caliber .50.
70,000 rifle ball cartridges, caliber .50.
7,000 rifle blank cartridges, caliber .50.
2,232,680 carbine ball cartridges, caliber .45.
4,954,974 rifle ball cartridges, caliber .45.
1,000 rifle ball cartridges, caliber .45 reloading.
284,900 rifle blank cartridges, caliber .45.
555,900 revolver ball cartridges, caliber .45.
184,800 revolver blank cartridges, caliber .45.
1,100 revolver ball catridges, caliber .44.
300 buckshot cartridges.
1,520,469 small-arm cartridge primers.
15,000 percussion caps.
20 pounds duck powder.
17,579 pounds rifle powder.
500 pounds shot.

AMMUNITION FOR FIELD GUN.

100 blank cartridges, 4.5-inch gun.
6,800 blank cartridges, 12-pounder mountain howitzer.
15,903 blank cartridges, 12-pounder gun.

5,000 blank cartridges, 6-pounder gun.
20,278 blank cartridges, 3-inch gun.
1,000 blank cartridges, 2 pounds charge.
730 blank cartridges, 1 pound charge.
3,818 blank cartridges, ½ pound charge.
38,000 lubricating disks.
133,000 paper dishs.
3,071 assorted fuses.
100 pounds quick match.
2 yards slow match.
1,000 pounds blasting powder.
16,805 pounds cannon powder.
8,000 pounds mammoth powder.
600 pounds mealed powder.
35,489 pounds mortar powder.
2,000 electric primers.
125,125 friction primers.

CLASS IX.

7 fencing bayonets, cadet.
103 whole blocks.
60 half blocks.
52 quarter blocks.
6 treble blocks.
2 quadruple blocks.
12 double blocks.
1 single block.
5 lifting blocks.
1 set blocks for mounting 15-inch gun.
2 sets pully blocks.
1 snatch block.
4 pointing boards.
2 cradle bolsters.
2 capstans.
2 hand carts.
1 sling chain.
2 sling cart chains.
4 trunnion chains.
17 gun chocks.
5 chocks, mechanical maneuvers, 15-inch gun.
45 roller chocks.
51 wheel chocks.
1 collar for gin.
1 cradle for moving heavy gun.
1 crane for 15-inch gun.
1 derrick.
1,000 disks, paper targets.
24 bulls eyes and centers A.
12 bulls eyes and centers B.
4 gin falls.
30 danger flags.
1 field and siege gin.
2 garrison gins.
2 gin handspikes.
1 lifting jack.

3 hydraulic jacks.
1 Laidley's gun lift.
2 lashing lines.
10 trunnion loops.
305 shot marks.
284 4-inch shot marks.
276 6-inch shot marks.
120 12-inch shot marks.
2,198,450 pasters for target.
34 shifting planks.
10 platforms for siege carriage.
13 platforms for mortar.
2 pulleys and falls.
4 trunnion rings.
19 cradle rollers.
4 derrick rollers.
4 half rollers.
24 long rollers.
10 short rollers.
6 trace ropes.
17 skids.
46 skidding pieces.
2 derrick shoes.
6 gin slings.
2 slings for cannon, rope.
11 brass stadia.
2 silver stadia.
6 stakes.
16 fencing swords, wood.
2 plane tables.
79 Laidley revolving targets.
6,508 paper targets, A.
6,412 paper targets, B.
1,950 paper targets, C.
325 intrenching tools.
8 store trucks.

CLASS X—II.

1 axle.
8 nave bands.
2 tire bands.
13 splinter bars.
1 axle body.
32 tire bolts.
6 turn buckles.
1 cheek.
17 ammunition chests.
2 trace clips with safety latches.
1 fulcrum.
18 fellies.
6 hasps for ammunition chests.
1,135 double spring hooks.
6 extractor hooks.
2 guide hooks.
3 pintle hooks.
1 counter hurter.

5 keys for ammunition chest.
5 keys and chains.
4 lunettes, caisson.
2 pounds nails.
30 assorted nuts.
70 linch-pins.
2 shaft eye-pins.
10 stay pins.
5 trail plates.
32 poles.
2 lashing ropes.
1 shaft saddle with roller frame for back strap.
6 elevating screws.
2 inside shafts.
2 outside shafts.
4 handspike sockets.
4 pole prop sockets.
32 spokes.
4 cap squares.
2 hooks and shaft-tugs.
2 battery wagon stocks.
3 caisson stocks.
5 field carriage stocks.
2 30-pounder carriage stocks.
2 mountain howitzer carriage stocks.
1 thill.
1 pintle transom with wheels, &c.
1 singletree with hooks.
30 assorted washers.
44 washers and nuts.
6 washers for end of main shaft.
86 linch washers.
12 pole yoke washers.
30 shoulder washers.
37 wheels complete.
6 wheels for Gatling carriage.
2 front traverse wheels.
2 rear traverse wheels.
10 pole yokes.

CLASS X—III.

6 artillery bits.
10 artillery curb bits, brass plated.
66 artillery bridles.
4 harness breechings.
490 brass plated buckles.
721 iron roller buckles.
12 halter chains.
39 collars.
2 cruppers.
33 girths.
12 leg guards.
17 halters.
2 hames.
66 rammer heads, 3-inch.
8 rammer heads, 6-pounder.

13 sponge heads, 3-inch.
11 sponge heads, 6-pounder.
36 cold shut links.
2,030 bridle ornaments.
36 pole pads.
2 bridle reins.
60 rosettes for artillery bridles.
6 drivers' saddles.
4 valise saddles.
130 woolen sponges, 3-inch.
6 woolen sponges, 4.5-inch.
53 woolen sponges, 6-pounder.
67 woolen sponges, 12-pounder.
4 woolen sponges, 200-pounder.
4 woolen sponges, 8-inch.
7 woolen sponges, mountain howitzer.
2 back straps.
2 breast straps.
228 halter straps.
51 hame straps.
3 loin straps.
44 pole straps.
4 stirrup straps.
46 woolen surcingles.
8 traces for Gatling cart harness.
27 lead traces.
27 wheel traces.
18 valises.
185 whips.
2 worms.

CLASS X—IV and V.

109 pounds lead balls.
227 metallic fuse plugs.
60 wooden fuse plugs.
100 sabots, 8-inch.
200 tin straps, 10-inch.
200 tin straps, 15-inch.

Parts of Springfield rifle, caliber .45.

217 lower bands.
212 upper bands.
451 band springs.
58 barrels.
430 bayonets.
144 bayonet clasps.
175 bayonet clasp screws.
256 breech blocks.
205 breech block caps.
1,918 breech block cap screws.
84 breech screws.
1,400 bridles.
1,412 bridle screws.
6 butt plates.

84 butt plate screws.
74 cam latches.
1,967 cam latch springs.
4,369 ejector springs.
4,739 ejector spring spindles.
264 ejector studs.
1,159 extractors.
2,067 firing pins.
1,797 firing pin screws.
67 firing pin springs.
224 front sights.
200 front sight pins.
4 guard bows.
100 guard bow nuts.
209 guard bow swivels.
807 guard bow swivel screws.
5 guard plates.
88 guard screws.
330 hammers.
366 hinge pins.
10 hinge pin studs.
1 lock.
5 lock plates.
1,116 main springs.
380 main spring swivels.
131 main spring swivel rivets.
88 ramrods.
642 ramrod stops.
4,776 rear sights.
54 rear sight bases.
1,260 rear sight base screws.
410 rear sight base springs.
207 rear sight leaves.
402 rear sight joint pins.
422 rear sight slides.
422 rear sight slide springs.
430 rear sight slide spring rivets.
2 receivers.
502 sears.
1,717 sear screws.
1,031 sear springs.
513 sear spring screws.
74 side screws.
32 side screw washers.
144 stocks, complete.
694 stocks, wood part.
412 tang screws.
9 thumb-pieces.
5 tip screws.
7 tips for stocks.
71 triggers.
305 trigger screws.
435 tumblers.
2,040 tumbler screws.
112 pistol gripes for officer's rifle.

Parts of Springfield carbine, caliber .45.

92 bands.
202 stacking bands.
48 band springs.
350 barrels.
50 barrel studs.
20 breech block caps.
479 breech block cap screws.
11 breech screws.
380 bridles.
406 bridle screws.
30 butt plate screws.
22 cam latches.
472 cam latch springs.
1,197 ejector springs.
1,153 ejector spring spindles.
20 ejector studs.
320 extractors.
804 firing pins.
632 firing pin screws.
65 firing pin springs.
785 front sights.
744 front sight pins.
45 guard bows.
10 guard bow nuts.
5 guard plates.
43 guard screws.
14 hammers.
48 hinge pins.
10 hinge pin studs.
277 main springs.
52 sears.
429 sear screws.
329 sear springs.
70 sear spring screws.
112 side screws.
195 rear sights, patent 1879.
5,556 rear sights, complete.
256 rear sight bases.
88 rear sight base screws.
42 rear sight base springs.
266 rear sight leaves.
32 rear sight joint pins.
95 rear sight slides.
81 rear sight slide springs.
81 rear sight slide spring rivets.
233 stocks, complete.
1,107 stocks, wood part.
140 swivel bars.
141 swivel bar rings.
75 tang screws.
22 thumb pieces.
13 triggers.
47 trigger screws.
17 tumblers.
502 tumbler screws.

Parts of Hotchkiss carbine and rifle, caliber .45.

20 cartridge stops.
149 cartridge stop pins.
125 cut-offs.
10 escutcheon screws.
150 extractors.
40 firing pins.
179 firing pin screws.
100 firing pin springs.
46 magazine springs.
517 main springs.
5 guard screws, front.
5 guard screws, rear.
5 sear springs.
5 sear spring screws.
5 side screws.
37 stocks, wood part, carbine.
32 stocks, wood part, rifle.
10 triggers.
35 trigger catches.
35 trigger catch pins.
149 trigger pins.
149 trigger spring screws.

Parts of Colt's revolver, caliber .45.

201 back strap screws.
205 bolts.
172 bolt screws.
34 center pins.
7 center pin bushings.
98 center pin catch screws.
130 center pin screws.
100 ejector heads.
70 ejector rods.
169 ejector springs.
50 ejector tubes.
229 ejector tube screws.
60 ejector tube springs.
182 firing pins.
176 firing pin rivets.
5 gate catches.
233 gate catch screws.
10 gate catch springs.
52 gate springs.
209 guard screws, long.
213 guard screws, short.
17 hammers.
172 hammer screws.
185 hands.
172 hand springs.
15 latch springs.
187 main springs.
172 main spring screws.
20 sear springs.

22 sear spring screws.
5 sear and stop bolt screws.
147 sear and stop bolt springs.
147 sear and stop bolt spring screws.
208 stocks.
50 stop bolt screws.
125 triggers.
238 trigger screws.

Parts of Schofield's Smith & Wesson revolver, caliber .45.

7 barrel catches.
112 barrel catch screws.
137 barrel catch springs.
13 base pins.
3 cylinder catches.
156 cylinder catch cams.
25 cylinder catch cam screws.
181 cylinder catch screws.
6 extractors.
137 extractor springs.
8 extractor stems.
6 extractor studs.
112 guard screws.
100 hammer studs.
30 hands.
106 hand pins.
141 hand springs.
106 joint pivots.
106 joint pivot screws.
4 lifters.
45 main springs.
20 main spring swivels.
20 pawls.
105 pawl pins.
120 pawl springs.
50 side plate screws, long.
50 side plate screws, short.
20 sights.
100 steady pins.
26 stops.
112 stop pins.
125 stop springs.
20 stocks.
100 stock pins.
100 stock screws.
31 strain screws.
100 swivel pins.
60 triggers.
106 trigger pins.
57 trigger springs.
112 trigger spring pins.

Parts of breech-loading shot guns.

6 bridles, left-hand.
12 bridle screws.

6 cones.
6 guard screws, front.
6 guard screws, rear.
2 locks, complete.
4 hammers, left-hand.
6 lifter springs.
6 main springs, left-hand.
6 main spring swivels, left-hand.
6 plungers.
6 sears.
8 sear springs, left-hand.
6 sear spring screws.
6 side screws.
3 stock butts.
4 triggers.
6 tumblers, left-hand.
6 tumbler screws.
6 trips.
6 trip springs.
5 scabbards, nickel-plated, officers' swords.
13 steel scabbards, musicians' swords.

CLASS X.—VII.

500 leather bayonet scabbard attachments.
537 saber belt attachments.
350 curb bits.
6 watering bits.
1,204 halter bolts.
15,752 brass bar buckles.
180 brass plated buckles.
7,972 brass wire buckles.
2,112 iron bar buckles.
3,816 iron roller buckles.
3,906 canteen corks and chains.
45 curb chains.
216 halter chains.
14,522 canteen covers.
1,012 brass D's for cartridge belts.
300 escutcheons.
14,000 canteen eyes.
1,064 side line fasteners.
30 bridle headstalls.
1,000 stirrup hoods.
1,130 brass snap hooks, for sabers.
500 double hooks for bayonet scabbard frogs.
60 sweat leathers, pairs.
3,132 curb strap loops.
2,079 ovals.
997 mouth pieces for curb bit.
35 curb bridle reins.
1,000 carbine sling swivel spring rivets.
2,139 brass rings.
1,468 D-rings.
1,316 halter rings.
1,548 iron rings.

60 swivel rings for halter.
20 rivets for trowel bayonet scabbard.
187 shields.
6,282 snaps for lariats.
62 snaps for links.
144 snaps for side lines.
500 carbine sling swivel springs.
1,204 halter squares.
1,070 brass foot staples.
2,415 brass staples for rings.
12,464 canteen straps.
3,642 clothing bag straps.
1,157 coat straps.
12 coupling straps.
661 curb straps.
8,312 halter straps.
200 halter hitching straps.
854 haversack straps.
167 hook straps.
200 saddle bag studs.
44 brass tips for trowel bayonet scabbard.
3,172½ yards linen webbing, 4 inches wide.
1,940 5/12 yards linen webbing, 7½ inches wide.
108 yards girth webbing, 4½ inches wide.

Class X—VIII.

1,282,100 rifle bullets, lubricated, caliber .45.
38,000 rifle bullets, 500 grains, patched.
13,500 cartridge cases for long range rifles.
200 cartridge cases for shot-gun.
5,000 lubricating wads for cartridges.
122,000 paper wads.
1,400 cartridge bags, ½-pound charge.
500 cartridge bags, 2-pound charge.
79,000 cartridge bags, 6-pounder gun.
5,200 cartridge bags, 3-inch gun.
11,546 cartridge bags, 12-pounder gun.
4,345 cartridge bags, mountain howitzer.
990 cartridge bags, 4½-inch gun.
600 cartridge bags, 24-pounder howitzer.
1,000 cartridge bags, 32-pounder gun.
100 cartridge bags, 42-pounder gun.
500 cartridge bags, 8-inch rifle.
100 cartridge bags, 8-inch Rodman gun.
855 cartridge bags, 10-inch Rodman gun.
500 cartridge bags, 15-inch Rodman gun.
500 cartridge bags, 100-pounder gun.
645 cartridge bags, 300-pounder gun.

Class X—IX.

1 lever for gun lift.
1 pole for hand cart.
1 pole for sling cart.
6 gin shoes.

65 Laidley target-frames, 6 by 6 feet.
2 Laidley target-frames, 6 by 12 feet.
1 set-iron posts for target.
70 target-frames, 4 by 6 feet.

PART SECOND.

$103\frac{1}{2}$ yards burlap.
$16\frac{2}{3}$ feet card clothing.
$1,944\frac{5}{12}$ yards cotton cloth, for targets.
30 pounds rocket cord.
$223\frac{3}{4}$ pounds sash cord.
117 pounds waste cotton.
456 yards cotton duck.
18 pounds packing flax.
$\frac{1}{2}$ pound goat's hair.
52 pounds marline.
125 yards muslin.
48 pounds oakum.
$3,262\frac{1}{2}$ pounds assorted rope.
$213\frac{1}{4}$ pounds assorted thread.
18 pounds patent linen thread.
$231\frac{1}{2}$ pounds saddlers' thread.
845 pounds shoe thread.
25 pounds tow.
$346\frac{3}{8}$ pounds twine.
$113\frac{1}{2}$ pounds woolen yarn.
20 yards cartridge bag material.
10 pounds lampwicking.
12 papers iron brads.
20 pounds brads.
$18\frac{1}{2}$ pounds bar brass.
$11\frac{1}{4}$ pounds sheet brass.
16 iron bolts.
2 feet iron chain.
500 gas checks.
26 pounds bar copper.
$13\frac{1}{2}$ pounds sheet copper.
10 pounds steel filings.
8 hasps and staples.
48 pairs brass butt hinges.
8 pairs hinges.
$1,192\frac{1}{2}$ pounds bar iron.
107 pounds hoop iron.
25 pounds nail-rod iron.
235 padlocks.
10 pounds copper nails.
1,260 pounds horseshoe nails.
1,782 pounds iron nails.
240 saddle nails, japanned.
180 saddle nails.
1,000 escutcheon pins.
$27\frac{1}{3}$ gross escutcheon pins.
10 pounds escutcheon pins.
76 gross brass screw pins.
8 cast iron plates.
207 pounds assorted rivets and burrs.

196½ pounds brass rivets and burrs.
721½ pounds copper rivets and burrs.
238½ pounds iron rivets and burrs.
6 iron rods.
174½ gross brass screws.
83 gross iron screws.
9,714 horseshoes.
2 cast iron sinks.
66¾ pounds solder.
50 pounds spikes.
369 pounds bar steel.
10 pounds spring steel.
47 pounds toe-calk steel.
92 papers copper tacks.
62⅝ pounds copper tacks.
858,000 iron tacks.
578 papers iron tacks.
159⅝ pounds iron tacks.
2 boxes sheet tin.
2 pounds brass wire.
10 pounds steel wire.
145 feet belting leather.
1,637 sides bridle leather.
27,199½ pounds harness leather.
4 sides lacing leather.
2 feet scratch leather.
6 calf-skins.
89 chamois-skins.
5 sheep-skins.
6,579 feet boards.
1,650 feet plank.
652 feet scantling.
1,635 feet timber.
100 pounds boracic acid.
1½ pounds muriatic acid.
45 pounds sulphuric acid.
54 gallons alcohol.
58 pounds gum arabic.
4 gross elastic bands.
110 pounds nitrate baryta.
615 quarts leather blacking.
452 instruction books.
445 pounds bone.
10 pounds borax.
102 bath bricks.
39 Bristol bricks.
13 ounces bristles.
59 pounds camphor.
30 pounds candles.
10 pounds red chalk.
76 pounds white chalk.
61 quires crocus cloth.
1,296½ quires emery cloth.
10 pounds animal charcoal.
2 barrels pulverized charcoal.
6,450 pounds coal.

135 pounds ammoniated sulphate of copper.
20 pounds sulphate of copper.
49¼ gallons Japan drier.
30 pounds patent drier.
32 pounds emery.
1,000 envelopes.
4 boxes paper fasteners.
27 pounds emery flour.
41 pounds glue.
50 pounds white glue.
7 boxes wheel grease.
1,038 pounds wheel grease.
30 pounds gutta percha.
3 hektographs.
5 boxes ingredients for blacking.
5 bottles black ink.
12 bottles hektograph ink.
1 bottle red ink.
1 set drawing instruments.
331½ gallons lacquer.
52 papers lampblack.
86 pounds lampblack.
1,591 pounds red lead.
2,475 pounds white lead.
8 pounds logwood.
2 boxes cleaning material.
25 pounds polishing material.
85 pounds scouring material.
40 quarts browning mixture.
1 bottle mucilage.
500 pounds refined niter.
175 gallons burning oil.
38½ quarts cosmoline oil.
7,419 pounds harness oil.
208 gallons kerosene oil.
19 gallons lard oil.
1,381 2/6 gallons linseed oil.
245½ gallons neatsfoot oil.
25½ gallons neutral oil.
1,369¼ gallons sperm oil.
12 gallons sweet oil.
10 feet rubber packing.
2,018 pounds black paint.
50 pounds green paint.
712 pounds lead-color paint.
150 gallons metallic paint.
3,755 pounds metallic paint.
4,453 pounds olive paint.
322 pounds red paint.
10 pounds white paint.
5 pounds chrome-yellow paint.
40 pounds drawing paper.
60 quires drawing paper.
24 5/12 quires emery paper.
827 pounds laboratory paper.
1 ream letter paper.

24 pounds log paper.
1 ream note paper.
550 pounds rocket and portfire paper.
130⅙ quires sand papers.
113 pounds stencil paper.
25½ pounds target paper.
620 pounds wrapping paper.
1 ream wrapping paper.
1¾ pounds paraffine.
24 lead pencils.
3 gross metallic pens.
6 penholders.
15 pounds black pepper.
1 pound red pepper.
11¼ pounds leather polish.
274 pounds chlorate of potash.
137 pounds putty.
30 pounds rosin.
55 pounds gum shellac.
52 bars castile soap.
2,862 pounds castile soap.
271 pounds common soap.
126 pounds sponge.
705½ pounds rotten stone.
220 pounds nitrate of strontia.
300 pounds flowers of sulphur.
5,000 shipping tags.
104 pounds tallow.
½ barrel coal tar.
418 gallons coal tar.
15 pounds tobacco.
803 papers tripoli.
1,067⅛ gallons turpentine.
4 pounds burned umber.
4 pounds raw umber.
13 gallons varnish.
3 bottles vasaline.
5 pounds vermillion.
313¾ pounds beeswax.
499½ pounds black wax.
131 pounds sealing wax.
10 gallons whisky.
186 3/16 pounds whiting.
12 lamp wicks.
5 pounds sulphate of zinc.

Tools, &c.

3 assorted adzes.
2 andirons.
3 anvils.
17 leather aprons.
11 augers and handles.
197 assorted awls.
1 brad awl and handle.
4 peg awls and handles.

1,035 saddlers' awls.
2 scratch awls.
3 seat awls and handles.
2 stub awls and handles.
6 assorted axes.
15 felling axes.
2 hand axes.
2 canvass mail bags.
15 bags for tacks, wax, &c.
5 tool bags for saddlers' and smiths' tools.
2 crowbars.
68 powder barrels.
336 metallic powder barrels.
456 wood powder barrels.
1 spring balances.
3 baskets.
2 smiths' bellows.
1 bevel.
45 assorted bits.
13 bits for brace.
7 saw blades.
1 anvil block.
38 lead punching blocks.
4 plumb bobs.
40 bottles.
20 boxes for forge and battery wagon stores.
24 boxes for cleaning material.
9 boxes for parts small arms.
10 sets Evans' transportation boxes.
13 boxes for sets reloading tools.
1 packing box.
2 shoeing boxes.
80 assorted braces.
1 drill brace.
274 corn brooms.
16 assorted brushes.
30 dusting brushes.
12 marking brushes.
476 paint brushes.
69 sash brushes.
28 wire scratch brushes.
10 scrubbing brushes.
1 steel brush.
6 whitewash brushes.
23 galvanized iron water buckets.
6 wood water buckets.
2 buttresses.
1 calipers.
1,585 powder canisters.
3 oil cans.
1,490 tin cans.
68 pricking carriages.
1 book case.
40 Madigan's packing cases.
1 paper case.
5 chamois skin sword cases.

6 chairs.
7 channelers.
1,024 powder chargers.
1,472 arm chests.
2 forge chests.
5 tool chests.
49 assorted chisels.
4 firmer chisels.
35 saddlers' clamps.
6 clamps for picket lines.
2 vise clamps.
1 nail claw.
1 clock.
4 collets.
74 compasses.
6 iron creasers.
57 wood creasers.
1 set stencil cutters, figures and letters.
1 stencil cutter, period.
6 wad cutters.
2 desks.
15 crimping dies.
36 reloading dies.
27 resizing dies.
4 dies and taps.
2 dies, taps and stocks.
2 tin dippers.
18 drifts.
12 assorted drills.
1 set drills.
3 coopers' drivers.
33 oil droppers.
9 feather dusters.
37 primer extractors.
2 primer extractors and recappers.
6 faucets.
739 assorted files.
1 fixture.
3 assorted forks.
7 formers for paper shell.
14 formers for rockets.
16 copper funnels.
5 tin funnels.
2 saw frames.
10 assorted gauges.
2 carpenters' gauges.
6 combination cartridge gauges.
5 draw gauges.
13 gimlets.
12 assorted gouges.
13 firmer gouges.
5 grindstones with arbors and cranks.
1 rifle guide for star gauge points.
135 assorted hammers.
2 hand hammers.
2 riveting hammers.

6 saddlers' hammers.
3 shoeing hammers.
1 sledge hammer.
1 adze handle.
414 assorted awl handles.
5 patent awl handles.
11 ax handles.
13 chisel handles.
40 file handles.
6 pickax handles.
3 handbarrows.
1 hardies.
33 hatchets.
4 assorted hose.
2 grass hooks.
30 primer extractor hooks.
4 reaping hooks.
20 copper powder barrel hoops.
11 saddlers' horses.
7 stitching horses.
25 feet rubber hose.
1 branding iron.
4 clenching irons.
67 riveting irons.
11 rounding irons.
6 soldering irons.
8 jackscrews.
1 jig.
1 kettle.
400 assorted knives.
1 channel knife.
5 drawing knives.
3 gauge knives.
3 half round knives.
1 head knife.
6 putty knives.
3 saddlers' knives.
15 shoeing knives.
7 shoe knives.
15 splitting knives.
3 ladles.
1 step ladder.
3 chalk lines.
2 tape lines.
1 spirit level.
1 surveyors' level.
1 model for target.
84 assorted mallets.
1 mandrel.
6 mauls.
4 mills.
2 powder measures.
7 tape measures.
9 tin measures.
6,958 assorted needles.
4 collar needles.

5 papers glovers' needles.
60 papers saddlers' needles.
25 sail needles.
113 nippers.
1 collar palm.
3 dusting pans.
24 carpenters' pencils.
9 pickaxes.
7 pins.
102 primer extractor pins.
32 assorted pincers.
24 assorted planes.
1 smoothing plane.
1 face plate.
2 screw plates, with dies and taps, complete.
1 set stencil plates, letters and figures.
34 pliers.
4 caliber plugs.
1 poker.
1 marking pot.
1 pot for melting sealing wax.
4 watering pots.
1 saddlers' tool pouch.
5 pritchels.
2 nail pullers.
35 assorted punches.
1 fore punch.
11 hand punches.
1 nail punch.
13 primer punches.
47 reloading punches.
26 resizing punches.
176 saddlers' punches.
105 spring punches.
14 gun-racks.
1 smiths' rake.
4 wooden rakes.
115 rasps.
8 reamers.
1 chalk-line reel.
1 surveyors' leveling rod.
103 2-foot rules.
24 corn sacks.
22 assorted saws.
1 compass saw.
3 cross-cut saws.
1 tennon saw.
3 counter scales.
1 platform scales.
17 scissors.
2 box scrapers.
4 iron scrapers.
13 shell scrapers.
4 stockers' scrapers.
78 screw-drivers.
40 screw-drivers for brace.
2 screw plate.

20 scythes.
78 burr or rivet sets.
2 saw sets.
13 primer setters.
87 shears.
4 stockers' shavers.
15 assorted shovels.
8 long-handled shovels.
6 sickles.
5 sieves.
4 sledges.
45 slickers.
104 magazine slippers.
16 scythe snaths.
13 safety sockets.
16 spades.
3 spokeshaves.
6 squares.
4 stakes.
6 seal stamps.
2 grindstone stands.
8 straight starters.
1 sharpening steel.
1 bit stock.
2 die stocks, with dies and taps, complete.
1 drill stock.
58 oil stones.
109 sand stones.
22 scythe stones.
3 stoves, heating.
1 straightedge.
4 primer extractor teeth.
110 thimbles.
46 ticklers.
5 tongs.
47 claw tools.
131 edge tools.
23 hand tools.
22 priming tools.
34 sets cartridge-reloading tools.
9 reloading tools.
277 sash tools.
1 set saddlers' tools.
1 surveyors' tripod.
2 trestles for Laidley cavalry forge.
1 trowel.
5 assorted vises.
2 bench vises.
2 forge vises.
2 hand vises.
201 pricking wheels.
7 wheelbarrows.
2 brush wipers, for cartridge shell.
7 assorted wrenches.
3 powder-barrel wrenches.
11 screw wrenches.
1 wrench and plug for vent piece.

APPENDIX 3.

Apportionment of ordnance, ordnance stores, &c., for the fiscal year ending June 30, 1880, *under sections* 1661 *and* 1667 *Revised Statutes United States, and regulations established in conformity therewith.*

States and Territories.	Number of Senators and Representatives.	Money-value.
Alabama	10	$4,797 85
Arkansas	6	2,878 71
California	6	2,878 71
Colorado	3	1,439 36
Connecticut	6	2,878 71
Delaware	3	1,439 36
Florida	4	1,919 14
Georgia	11	5,277 64
Illinois	21	10,075 49
Indiana	15	7,196 78
Iowa	11	5,277 64
Kansas	5	2,398 93
Kentucky	12	5,757 42
Louisiana	8	3,838 28
Maine	7	3,358 50
Maryland	8	3,838 28
Massachusetts	13	6,237 21
Michigan	11	5,277 64
Minnesota	5	2,398 93
Mississippi	8	3,838 28
Missouri	15	7,196 78
Nebraska	3	1,439 36
Nevada	3	1,439 36
New Hampshire	5	2,398 93
New Jersey	9	4,318 06
New York	35	16,792 48
North Carolina	10	4,797 85
Ohio	22	10,555 27
Oregon	3	1,439 36
Pennsylvania	29	13,913 76
Rhode Island	4	1,919 14
South Carolina	7	3,358 50
Tennessee	12	5,757 42
Texas	8	3,838 28
Vermont	5	2,398 93
Virginia	11	5,277 64
West Virginia	5	2,398 93
Wisconsin	10	4,797 85
Arizona Territory*	3	1,439 36
Dakota Territory*	3	1,439 36
Idaho Territory*	3	1,439 36
New Mexico Territory*	3	1,439 36
Montana Territory*	3	1,439 36
Utah Territory*	3	1,439 36
Washington Territory*	3	1,439 36
Wyoming Territory*	3	1,439 36
District of Columbia*	3	1,439 36
Total	396	189,995 00
Freights, &c		11,005 00
		200,000 00

*Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

APPENDIX 4.

Statement of ordnance, ordnance stores, &c., distributed to the militia from July 1, 1879, to June 30, 1880, under sections 1661 and 1667, Revised Statutes United States.

CLASS I.

4 12-pounder bronze guns.
2 12-pounder mountain howitzers.
4 Gatling guns, 10 barrels, long, caliber .45.

CLASS II.

2 carriages for 6-pounder guns.
1 carriage for light 12-pounder-gun.
6 carriages and limbers for light 12-pounder guns.
2 carriages and limbers for 12-pounder mountain howitzers.
4 carriages and limbers for 10-pounder Parrott guns.
4 carriages and limbers for Gatling guns, caliber .45.
2 caissons and limbers for light 12-pounder guns.

CLASS III.

10 sponge buckets, iron, for field guns.
8 tar buckets, iron, for field guns.
4 watering buckets, leather.
6 front sights for light 12-pounder guns.
4 fuze cutters.
24 gunners' haversacks.
12 gunners' gimlets.
4 gunners' calipers.
2 gunners' levels.
12 gunners' pincers.
2 gunners' quadrants.
22 handspikes, trail.
4 sets of artillery harness, 2 horses, wheel.
6 sets of artillery harness, 2 horses, lead.
14 paulins, 12 by 15 feet.
5 pendulum hausses.
1 pendulum hausse-pouch.
12 lanterns.
25 lanyards for friction primers.
13 prolonges.
10 priming wires.
4 sponges, woolen, 10-pounder gun.
16 sponges, woolen, light 12-pounder gun.
4 sponge covers, 3-inch gun.
5 sponge covers, 6-pounder gun.
14 sponge covers, light 12-pounder gun.
4 sponges and rammers, 3-inch gun.
7 sponges and rammers, 6-pounder gun.

18 sponges and rammers, light 12-pounder gun.
8 harness sacks.
26 thumbstalls.
3 tompions for light 12-pounder gun.
4 tow hooks.
20 tube pouches.
11 vent covers.
8 vent punches.
36 artillery whips.
11 worms and staves for field guns.

Class V.

104 12-pounder shot, fixed.
35 3-inch shells, fully prepared.
24 12-pounder mountain howitzer shells, strapped and fixed.
65 3-inch case shot, fully prepared.
50 2.9-inch canister, fully prepared.
192 12-pounder canister, fixed.
79 12-pounder mountain howitzer canister, filled.

Class VI.

Muzzle-loading.

8 Springfield rifle muskets, caliber .58.

Breech-loading.

1,775 Springfield rifles, caliber .50.
120 Springfield rifles, cadet, caliber .50.
6,879 Springfield rifles, caliber .45.
150 Springfield rifles, cadet, caliber .45.
16 Springfield rifles, officer's model, caliber .45.
702 Springfield carbines, caliber .45.
501 Colt's revolvers, caliber .45.
131 Schofield's Smith & Wesson revolvers, caliber .45.
69 officers' swords.
103 non-commissioned officers' swords.
297 light cavalry sabers.
164 artillery sabers.
72 bayonets for caliber .50 rifles.
16 trowel bayonets.

Class VII.

1 set infantry equipments.
6,559 steel bayonet scabbards.
151 leather bayonet scabbards.
136 trowel bayonet scabbards.
558 cartridge belts, caliber .45.
4,792 cartridge boxes, caliber .45.
71 cartridge boxes, caliber .50.
259 cartridge boxes, caliber .58.
1 cartridge box, pattern 1872.
310 carbine cartridge pouches.

96 pistol cartridge pouches.
400 carbine slings and swivels.
50 carbine sling swivels.
60 carbine sockets and straps.
100 currycombs.
3,827 gun slings.
100 horse brushes.
320 haversacks and straps.
370 canteens and straps.
1,001 knapsacks and straps.
188 pistol holsters.
1,206 saber belts and plates.
600 saber belt plates.
156 saber knots.
100 pairs spurs and straps.
32 pairs sweat leathers.
7 saddle blankets.
4 artillery drivers' saddles.
4 artillery bridles.
129 cavalry saddles.
129 curb bridles.
1 valise.
6,134 waist belts and plates.
20 non-commissioned officers' waist belts and plates.
56 non-commissioned officers' shoulder belts and plates.
20 non-commissioned officers' sword frogs.

CLASS VIII.

438 blank cartridges for 10-pounder gun.
2,340 blank cartridges for 3-inch gun.
24 blank cartridges for light 12-pounder gun.
36,000 musket blank cartridges, paper, caliber .58.
1,105,465 rifle ball cartridges, caliber .50.
26,500 rifle blank cartridges, caliber .50.
299,000 rifle ball cartridges, caliber .45.
124,000 rifle blank cartridges, caliber .45.
34,200 carbine ball cartridges, caliber .45.
12,000 revolver ball cartridges, caliber .45.
7,000 revolver blank cartridges, caliber .45.
12,240 friction primers.
1,000 cartridge primers.
50 pounds musket powder.
1,000 pounds mortar powder.
10 portfires.
1,000 lubricated bullets, caliber .45.

CLASS X.

4 pole pads.
4 pairs pole straps.

Spare parts for Springfield rifle, caliber .50.

2 ejector springs.
274 firing pins.

2 rear-sight leaves.
2 rear-sight leaf slides.
3 rear-sight leaf screws.
1 receiver.
1 ramrod.
4 stocks.

Spare parts for Springfield rifle, caliber .45.

120 bayonets.
862 rear sights.
120 tumblers.

MISCELLANEOUS.

1 set hand reloading tools, caliber .45.

APPENDIX 5.

Statement of ordnance, ordnance stores, &c., distributed to colleges and universities, from July 1, 1879, to June 30, 1880, under section 1225 Revised Statutes United States, as amended by act approved July 5, 1876.

Class I.

2 6-pounder bronze guns.
8 3-inch wrought-iron guns.

Class II.

2 6-pounder gun carriages and limbers.
8 3-inch gun carriages and limbers.

Class III.

10 gunners' haversacks.
10 handspikes.
20 lanyards for friction primers.
10 priming wires.
10 paulins, 12 by 15 feet.
4 pendulum hausses.
4 seats for pendulum hausses.
4 pouches for pendulum hausses.
4 sponges and rammers for 6-pounder gun.
16 sponges and rammers for 3-inch gun.
4 sponge covers for 6-pounder gun.
16 sponge covers for 3-inch gun.
20 thumbstalls.
8 tompions for 3-inch gun.
10 tube pouches.
10 vent covers.

Class IV.

40 8-inch mortar shells, strapped.

Class VI.

393 Springfield "cadet" rifles, caliber .45.
124 light cavalry sabers.
6 non-commissioned officers' swords, steel scabbards.

Class VII.

6 non-commissioned officers' shoulder belts and plates.
100 saber belts and plates.
393 steel bayonet scabbards.
67 leather bayonet scabbards.
393 cartridge boxes, caliber .45.
393 waist belts and plates.
31 waist belts.

CLASS VIII.

1,100 blank cartridges for 6-pounder gun.
600 blank cartridges for 3-inch gun.
200 blank cartridges for 12-pounder gun.
7,000 carbine ball cartridges, caliber .50.
1,000 rifle ball-cartridges, caliber .45.
13,000 carbine ball-cartridges, caliber 45.
7,000 rifle and carbine blank cartridges, caliber .50.
12,000 rifle and carbine blank cartridges, caliber .45.
5,700 friction primers.
40 time fuses for 8-inch mortar shells.

APPENDIX 6.

Statement of ordnance stores, &c., distributed to the Territories and States bordering thereon, from July 1, 1879, *to June* 30, 1880, *under the joint resolutions of July* 3, 1876, *March* 3, 1877, *and June* 7, 1878, *and the act of May* 16, 1878.

300 Springfield rifles, caliber .50.
300 leather bayonet-scabbards.
300 cartridge boxes, caliber .58.
300 gun slings.
300 waist belts and plates.
30,000 rifle ball-cartridges, caliber .50.

APPENDIX 7.

Statement of ordnance stores issued to the Executive Departments under the provisions of the act of March 3, 1879.

TO THE TREASURY DEPARTMENT.

84 Springfield carbines, caliber .45.
50 carbine slings.
50 carbine cartridge-pouches.
8 carbine slings and swivels.
8 cartridge boxes.
58 waist belts and plates.
8, 000 carbine ball-cartridges, caliber .45.

REPORTS OF THE CONSTRUCTOR OF ORDNANCE.

OFFICE OF THE CONSTRUCTOR OF ORDNANCE,
New York, September 28, 1880.

SIR: I have the honor to transmit herewith the following papers and plates to accompany your annual report for the current year, viz:

Construction report of a 3.17-inch muzzle-loading rifle.

Construction report of a 3.18-inch breech-loading chambered rifle; with two plates.

Construction report of a field carriage for a 3.18-inch breech-loading rifle; with two plates.

Construction report of an 8-inch muzzle-loading rifle (converted), with an increased pitch of rifling.

Construction report of an 8-inch muzzle-loading chambered rifle (converted); one plate.

Progress report on experimental cannon powders.

Tests of bar iron used in the fabrication of wrought-iron tubes for converted rifles.

The progress report on powder, and the report on the tests of bar iron used in the construction of tubes for converted rifles, were specially prepared; the former by Capt. Charles S. Smith, and the latter by Lieut. C. W. Whipple; and I am largely indebted to their services in the preparation of the remaining reports.

Very respectfully, your obedient servant,

S. CRISPIN,
Bvt. Col., U. S. A., Lieut. Col. of Ordnance,
Constructor of Ordnance.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.

APPENDIX 8.

CONSTRUCTION REPORT OF A 3.17-INCH MUZZLE-LOADING RIFLE.

This gun was bored out to the same diameter as 3.17-inch muzzle-loading rifle, rapid twist, constructed last year (see Report of Chief of Ordnance for 1879), and re-rifled with its original twist, number of grooves, &c., in order to afford the means of accurate comparison between the two systems of rifling employed.

DESCRIPTION.

RIFLING.

Number of lands and grooves	7
Width of lands	0.5776 inch.
Width of grooves	0.846 inch.
Depth of grooves	0.075 inch.

Twist uniform, one turn in 10 feet.

The rifling stops at 4 inches from the bottom of the bore.

FABRICATION.

The gun selected for this alteration was 3-inch wrought-iron rifle, No. 778, and the work was performed at the West Point foundry.

The gun was simply bored to the required diameter, and then re-rifled.

INSPECTION.

After star-gauging, the gun was shipped to the Sandy Hook proving ground.

APPENDIX 8*a*.

CONSTRUCTION REPORT OF A 3.18-INCH BREECH-LOADING CHAMBERED RIFLE.

(Two plates.)

DESCRIPTION.

In its general features this gun resembles the 3-inch breech-loading rifle constructed last year, and described on pages 67 and 68 of the Report of Chief of Ordance for 1879.

Both guns are converted from 3-inch wrought-iron muzzle-loading rifles by cutting off the breech near the bottom of the bore, and screwing in from the rear a steel breech-receiver, which forms the rear end of the bore, and contains and supports a sliding breech-block.

But the 3.18-inch differs from the 3-inch rifle in the following details:

The breech block is cylindro-prismatic in shape, instead of prismatic.

The front of the block is hollowed out for the reception of a steel obturator-plate, in the place of a pressure plug inserted in the block of the first gun as a consequence of the experimental purposes for which it was intended.

The outward movement of the block is limited by a stud screwed through the top of the breech receiver.

The old lands are removed by boring to 3.18-inches, and the gun rerifled with a more rapid twist.

The capacity of the powder chamber is much increased and the vent placed at a greater distance from the bottom of the bore.

* RIFLING, CHAMBERING, AND VENTING.

Number of grooves and lands	22.
Width of lands	0.200 inch.
Width of grooves	0.254 inch.
Depth of grooves	0.04 inch.
Twist uniform, one turn in 7 feet.	

The chamber is 8.25 inches in length and 3.78 inches in diameter. In front of the mouth of the chamber, and for a length of 1.25 inches, the bore is enlarged to the bottom of the grooves, and the lands connected with this point by a bevel 1.0 inch in length.

The rear of the chamber is enlarged to form a seat for the gas check.

The vent is in a vertical plane passing through the axis, and at a distance of 3.75 inches from the bottom of the bore.

FABRICATION.

The gun selected for the conversion was 3-inch wrought-iron rifle, No. 774, and the work was performed at the West Point foundry.

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* It was the intention to make the lands narrower at the seat of the projectile than at the muzzle, to wit; width at the muzzle, 0''.2, width at seat of projectile 0''.16; but the necessary alterations of tools to do the work it was thought would consume too much time to carry out this intention, and the lands were therefore made of an uniform width throughout.

The breech receiver and block were made of Midvale steel tempered in oil.

Specimens of the steel, tested before and after tempering, gave the following results:

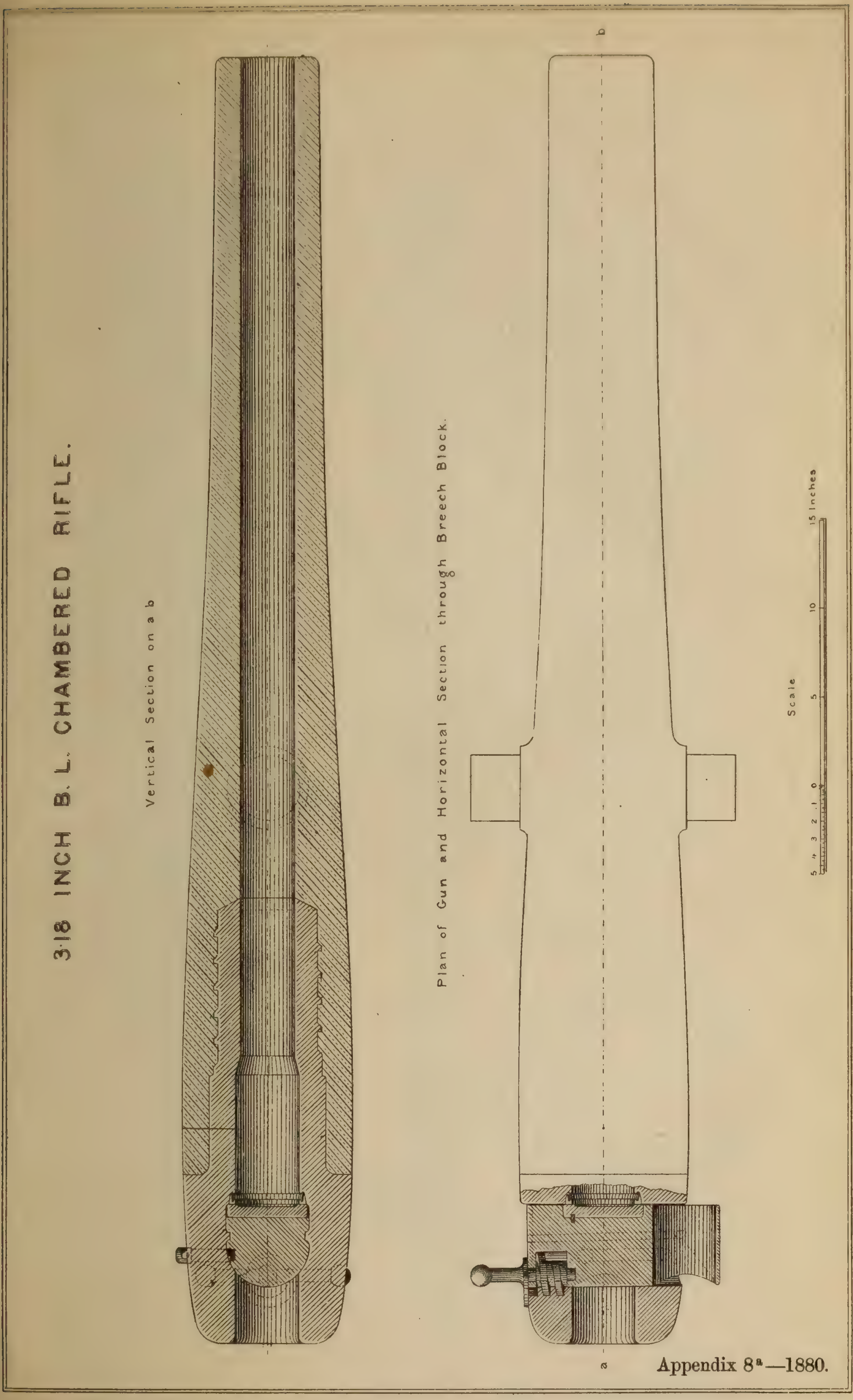
	Tenacity per square inch.	Extension per inch.
	Pounds.	*Inch.*
Before tempering	89, 639	0. 198
After tempering	111, 890	0. 14

INSPECTION.

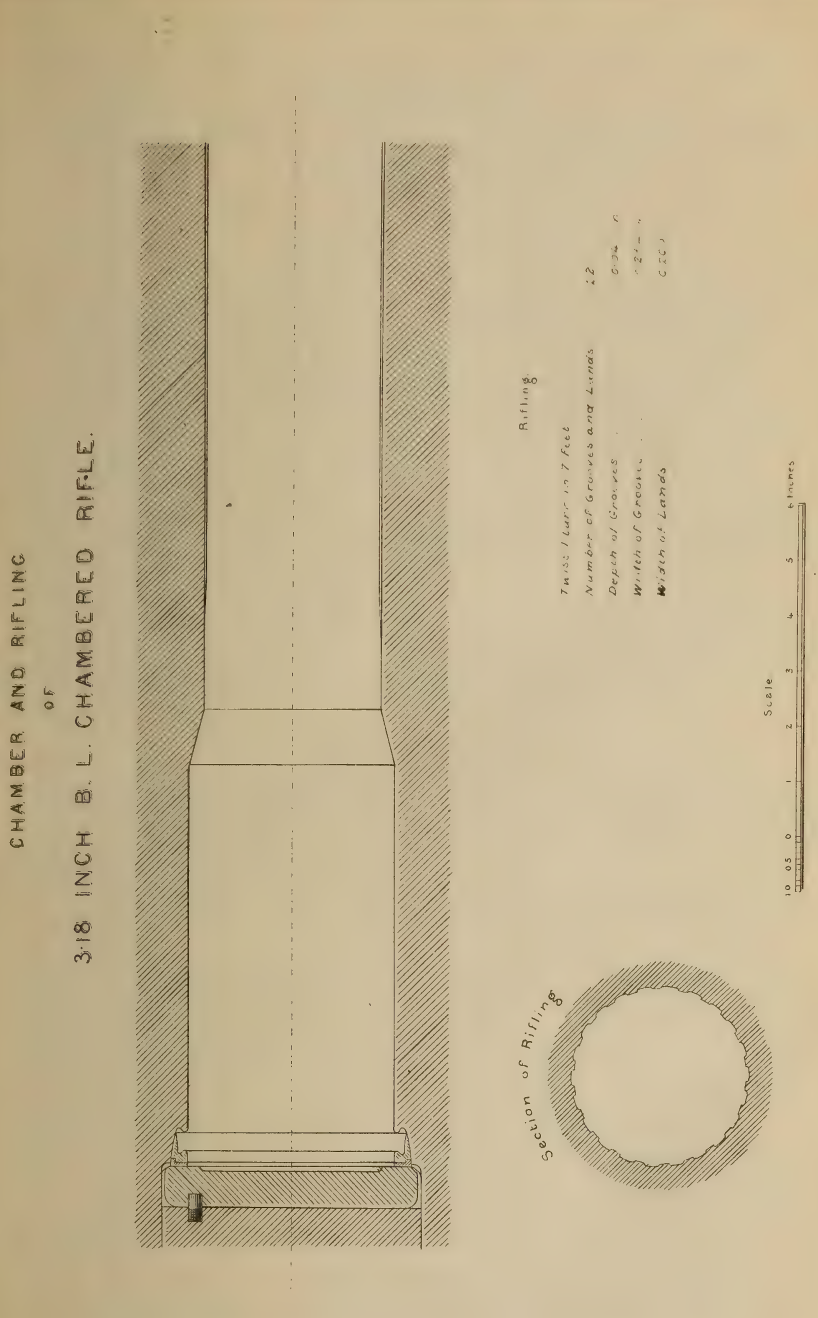
After the usual inspection, the gun was mounted on its carriage and shipped to Sandy Hook.

Principal dimensions.

Total length of converted rifle	inches	72. 65
Length of bore	do	64. 85
Length of rifled portion of bore	do	54. 35
Diameter of bore across lands	do	3. 18
Length of chamber	do	8. 25
Diameter of chamber	do	3. 78
Length of breech receiver in rear of casing	do	9. 5
Total length of breech receiver	do	25
Diameter of breech receiver over threads	do	6. 2
Length of screw in breech receiver	do	7. 5
Pitch of thread in breech receiver	do	1. 5
Length of breech block	do	10. 95
Width of breech block	do	4. 75
Number of grooves and lands	do	22
Width of grooves	do	0. 254
Width of lands	do	0. 2
Depth of grooves	do	0. 04
Pitch of rifling (uniform) one turn in	feet	7
Axis of vent from bottom of bore	inches	3. 75
Weight of gun	pounds	836
Preponderance	do	87



Appendix 8a—1880.



Appendix 8ª—1880.

APPENDIX 8*b*.

CONSTRUCTION REPORT OF A FIELD-CARRIAGE FOR 3.18-INCH BREECH-LOADING RIFLE.

(Two plates.)

PRELIMINARY REMARKS.

The advisability of substituting iron or steel for wood in the construction of the principal parts of the field-gun carriage was long since recognized, both in this country and abroad.

Experimental iron carriages were made under the direction of Colonels Rodman and Benton, as far back as 1866 and 1867, but the want of necessary appropriations, the number of serviceable wooden carriages on hand, and the small number required for issue, caused a continuation of the experiments to be postponed.

The success of the 3-inch breech-loading rifle, and the proposition to make and issue a battery of such guns for service, seemed to point to the present as a suitable occasion to investigate the subject of providing them with proper carriages.

The construction of the cheeks by re-enforcing them with angle iron was adopted from motives of economy and the desire to save time; it is contemplated, however, in future constructions of these gun-carriages, to form each cheek with its flanges from a single piece.

DESCRIPTION.

The main features of the 3.18-inch field-carriage are as follows:

1st. Two cheeks of steel plate $\frac{5}{16}$ inch thick, stiffened by angle-iron riveted on the inside along the edge, and reinforced by a small plate between the axle and the trunnions.

2d. A wrought-iron axle supporting the cheeks, and braced to the trail on each side by rods attached to the axle just inside of the shoulder-washer.

3d. A wrought-iron lunette plate securing the ends of the trail, and forming the support and point of attachment for the trail handspike.

4th. A middle and front transom, riveted to the inside of the cheeks, the one in rear of, and the other in front of, the axis of the trunnions.

5th. The elevating apparatus, composed of two screws, one working within the other; the outer, hollow, screw works in a nut which is pivoted to two brass supports, riveted to the cheeks of the trail.

6th. The trail-chest, for tools, composed of a single wrought-iron plate, bent to the proper shape, lined with wood, and riveted to the cheeks just in rear of the elevating screw; the lid of the chest is also of wrought iron, lined with wood, and is hinged to the front of the chest.

7th. The wooden wheel-brake with iron shoes, supported by the trail, and controlled by a screw working in a nut attached to the axle.

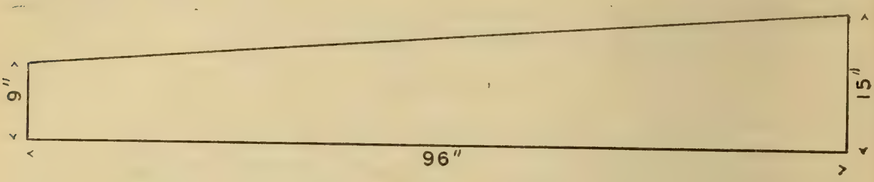
8th. The wheels, with steel tire, wooden spokes and fellies, and brass naves.

9th. A hollow iron trail handspike, with solid head, attached to the lunette plate; when not in use for pointing it is folded back over the trail and rests upon the lid of the chest.

FABRICATION.

The work was done by the West Point foundry.

The cheeks were furnished by the Nashua Steel Works, in the following shape:



The plates were first cut to the proper shape, the outline being laid out on them by means of a wooden pattern.

The angle-iron, with a flange of $1\frac{3}{4}$ inches, was then bent over the formers to the same outline, the ends being welded at the foot of the trail, and the two frames thus produced riveted each to their respective cheeks.

The wrought-iron trunnion-bed plates, each of which formed one continuous piece with the axle-bed, were then shaped and riveted to the angle-iron, and the reinforcing plates secured.

The next step was to assemble the cheeks. The heads of the cheeks were temporarily secured together while the lunette plate was attached; then the middle transom was riveted to the cheeks, and the small front transom and trail-chest added.

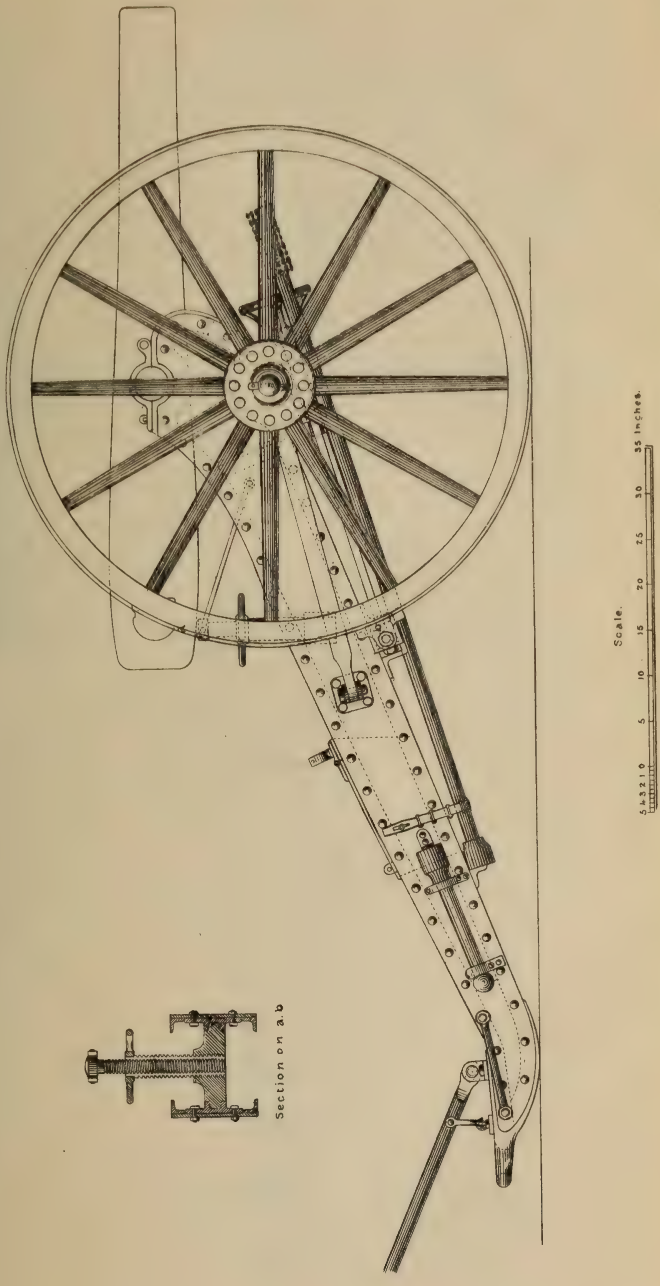
In the mean time the axle and braces had been forged, and the brake with its screw handle, and nut, the handspike, implement hooks, cap-squares, and other small parts prepared for attachment.

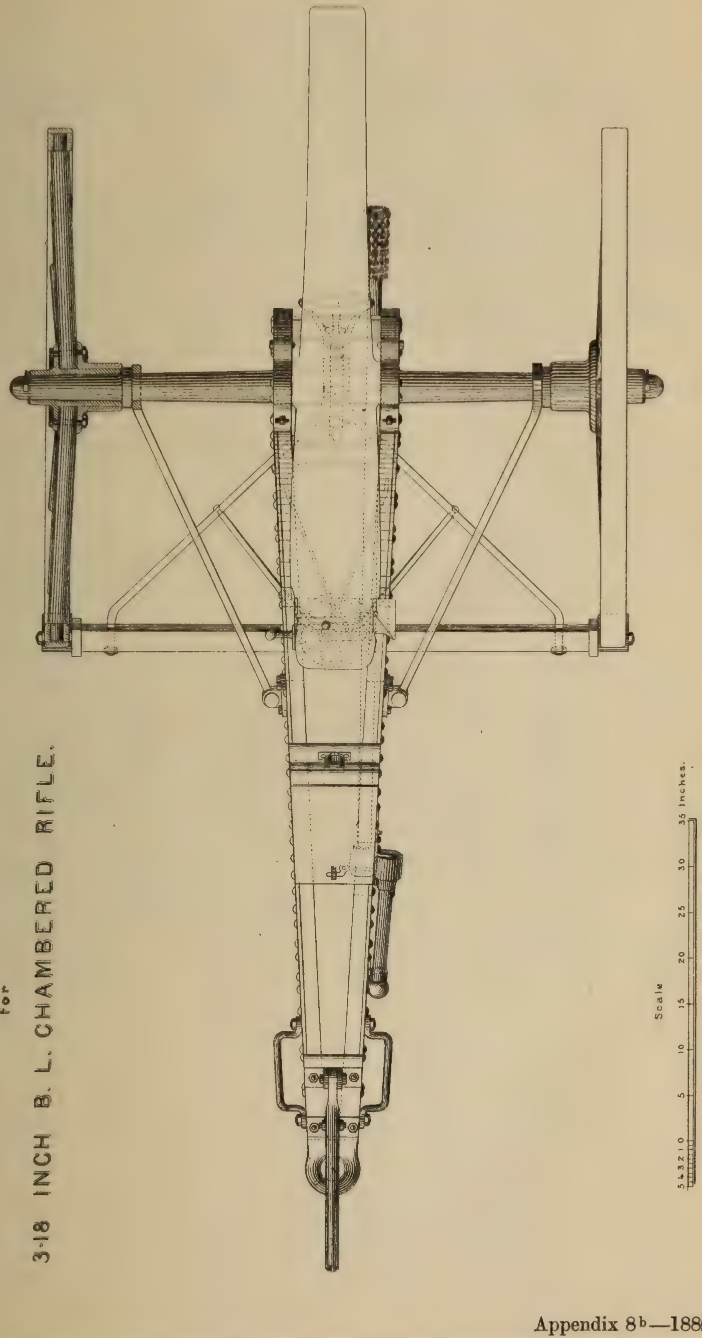
These parts, together with the elevating apparatus, having been fitted to the carriage, it was completed by the addition of the wheels which were made by W. H. Jackson, of Matteawan, N. Y.

Principal dimensions and weights of field-gun carriage for 3.18-*inch breech-loading converted rifle.*

Distance between the inside of the trunnion plates	inches	9.6
Diameter of the trunnion holes	do	3.7
Distance from axis of trunnions to axis of axle-tree	do	12.7
Height of axis of trunnions above the ground	do	41.2
Distance between the points of contact of trail and wheels with the ground line	inches	74.4
Distance from front of wheels to end of trail, the piece being in battery	do	116.6
Thickness of steel cheek-plates	do	$\frac{5}{16}$
Width of flange of reinforcing angle-iron	do	1.75
Whole length of axle	do	70.5
Wheels:		
Height of wheels	do	57
Track of the wheels	do	60
Dish of finished wheel	do	1.375
Diameter of brass nave	do	10.5
Spokes	number	12
Fellies	do	7
Weights:		
Carriage, without wheels	pounds	819
One wheel	do	180
Carriage complete without implements	do	1,179

CARRIAGE
for
3·18 INCH B. L. CHAMBERED RIFLE.





CARRIAGE
for
3·18 INCH B. L. CHAMBERED RIFLE.

APPENDIX 8c.

CONSTRUCTION REPORT OF AN 8-INCH MUZZLE-LOADING RIFLE (CONVERTED) No. 29, BREECH INSERTION, RAPID TWIST.

DESCRIPTION.

The only peculiarity which distinguishes this gun from other 8-inch converted rifles consists in its rifling, the details of which are as follows:

Number of lands and grooves	24
Width of lands	0.349 inch.
Width of grooves	0.6982 inch.
Depth of grooves	0.075 inch.

Twist, uniform; one turn in 30 feet.

FABRICATION.

The tube was made and work of conversion performed by the West Point foundry.

INSPECTION.

The usual inspections were made of all details, and the gun after completion shipped to Sandy Hook proving ground.

Principal dimensions.

Length of bore	inches..	117.25
Length of tube	do ...	120
Length of jacket over tube	do ...	43
Total length of finished tube	do ...	136.66
Interior diameter of jacket	do ...	10.50
Exterior diameter of tube under jacket	do ...	10.505
Diameter of finished tube from screw thread to first shoulder	do ...	14.698
Corresponding diameter of bore of casing	do ...	14.703
Diameter of finished tube from first shoulder to second shoulder	do ...	13.490
Corresponding diameter of bore of casing	do ...	13.494
Diameter of finished tube from second shoulder to third shoulder	do ...	11.481
Corresponding diameter of bore of casing	do ...	11.489
Diameter of finished tube from third shoulder to neck	do ...	10.490
Corresponding diameter of bore of casing	do ...	10.500
Weight of gun	pounds..	16,070
Counter preponderance	do....	168

APPENDIX 8*d*.

CONSTRUCTION REPORT OF AN 8-INCH MUZZLE-LOADING, CHAMBERED RIFLE, CONVERTED FROM A 10-INCH RODMAN SMOOTH-BORE, BY LINING, BY BREECH INSERTION, WITH A COILED WROUGHT-IRON TUBE, HAVING A JACKET SHRUNK ON EXTENDING THROUGH THE BREECH.

(One plate.)

DESCRIPTION.

The gun differs from 8-inch converted muzzle-loading rifle No. 1 (B. I.), described on page 352, Report of the Chief of Ordnance for 1878, in the following respects:

The shoulder upon the jacket of the tube is dispensed with, the jacket having a uniform diameter of 14.5 inches, except across the threads at its base, where the diameter is 15.3 inches. The bottom of the bore is enlarged so as to form a chamber of the following dimensions:

Length of cylindrical part	inches	22.267
Depth of cup at bottom	do	3.75
Length of bevel	do	2
Total length of chamber	do	28.017
Diameter of chamber	do	9
Volume of chamber	cubic inches	1,650
Powder capacity of chamber	pounds	62

As the breech-cup formed the bottom of the chamber, it was increased in length (depth and thickness of cup) from 5.50 inches to 6.50 inches.

RIFLING.

The rifling of the gun consists of 15 lands and grooves each, of equal width, and terminates upon the bevel of the chamber.

Width of lands and grooves	0.83776 inch.
Depth of grooves	0.073 inch.

Twist, uniform; one turn in 40 feet.

VENTING.

The old vent is closed (the copper bushing having been removed) by a wrought-iron screw-plug, and 2″.75 nearer the muzzle a new one is introduced, parallel to the vertical plane through the axis of the bore and distant from it 2.5 inches.

FABRICATION OF THE GUN.

The work of conversion was performed at the South Boston foundry. The gun selected for the conversion was 10-inch Rodman gun No. 73, manufactured at the Scott foundry, Reading, Pa., in the year 1864.

The tube and muzzle collar were manufactured at the West Point foundry of Ulster "tube-iron" by processes identical with those heretofore described, except that before the breech-cup was screwed into the base the tube was chambered. The operations of boring the casing,

turning the tube, fitting, insertion of the tube, &c., were similar to those employed in the conversion of 8-inch muzzle-loading rifle No. 1 (B. I.) above referred to.

INSPECTION.

The workmanship and finish of the gun were good in every respect.

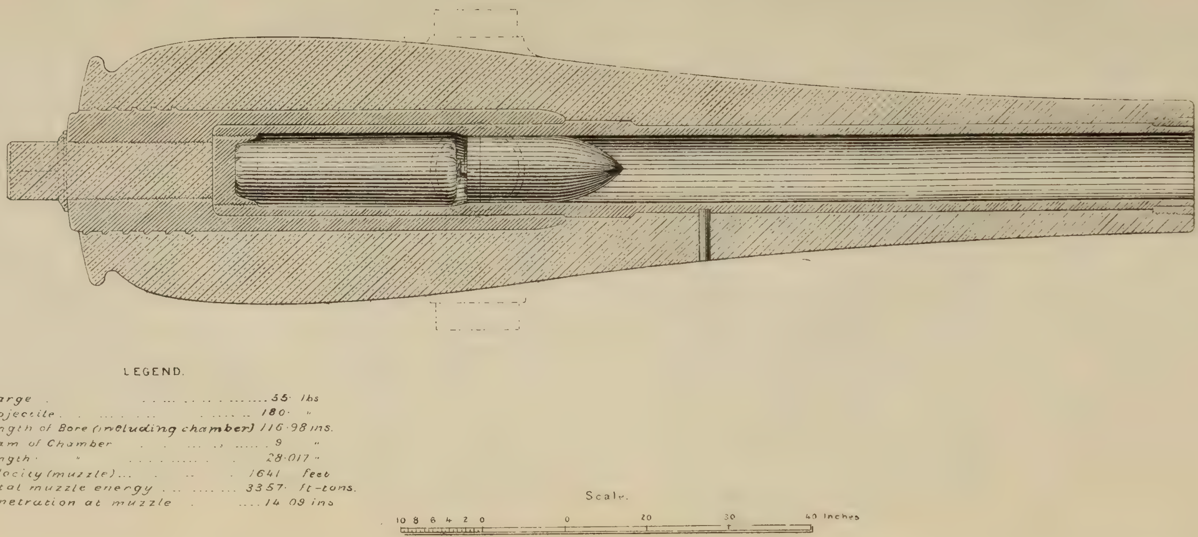
Principal dimensions.

Total length of complete tube (finished)	inches	137.43
Total length of bore of casing	do	136.05
Length of jacket (finished)	do	60.47
Diameter of finished tube from end of screw thread to first shoulder	do	14.5
Diameter of finished bore of casing from end of screw thread to first shoulder	inches	14.502
Corresponding play	do	.002
Diameter of finished tube from first shoulder to second shoulder	do	11.490
Diameter of finished bore of casing from first shoulder to second shoulder	inches	11.504
Corresponding play	do	.014
Diameter of finished tube from second shoulder to neck	do	10.647
Diameter of finished bore of casing from second shoulder to neck	do	10.657
Corresponding play	do	.010
Length of screw on jacket	do	14.20
Pitch of screw thread on jacket	do	2.54
Diameter of jacket across threads	do	15.30
Corresponding diameter of casing	do	15.31
Length of neck of tube under muzzle collar	do	5
Length of muzzle collar	do	5
Length of recess in casing*	do	5.65
Length of screw on muzzle collar	do	3.15
Length of screw on recess of casing	do	3.275
Excess in length of screw on collar over that on recess	do	.125
Diameter of tube over neck	do	9.736
Interior diameter of muzzle collar	do	9.746
Corresponding play	do	.010
Diameter of muzzle collar across threads	do	11.741
Diameter of recess on casing	do	11.762
Play between collar and casing	do	.021
Thickness of collar	do	1.003
Pitch of thread on collar	do	0.5
Length of bore (including chamber)	do	116.98
Length of rifling	do	89.24
Diameter of bore across lands	do	7.994 to 7.997
Width of grooves	do	0.83776
Width of lands	do	0.83776
Depth of grooves	do	0.073
Pitch of rifling, 1 turn in	do	480
Diameter of vent	do	0.20
Diameter of vent bushing	do	1
Axis of vent from bottom of bore	do	3.50
Axis of vent from vertical plane through axis of bore	do	2.50
Length of securing pin	do	6.20
Diameter of securing pin	do	1.50
Distance of securing pin from muzzle	do	60
Weight of gun	pounds	16,065

TABLE No. 1.—*Relative diameters of bore of cast-iron body of 10-inch gun and wrought-iron tube for insertion therein at different points of the cylindrical length.*

Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Difference.	Inches from face of muzzle.	Interior diameter of bore.	Exterior diameter of tube.	Difference.
	Inches.	*Inches.*	*Inch.*		*Inches.*	*Inches.*	*Inch.*
6	10. 657	10. 647	0. 010	81	14. 501	14. 999	0. 002
8	10. 656	10. 647	. 009	82	14. 501	14. 999	. 002
10	10. 657	10. 647	. 010	83	14. 502	14. 999	. 003
12	10. 657	10. 647	. 010	84	14. 502	14. 999	. 003
14	10. 657	10. 647	. 010	85	14. 502	14. 999	. 003
16	10. 657	10. 647	. 010	86	14. 501	14. 999	. 002
18	10. 657	10. 647	. 010	87	14. 501	14. 999	. 002
20	10. 657	10. 647	. 010	88	14. 501	14. 999	. 002
22	10. 657	10. 647	. 010	89	14. 501	14. 999	. 002
24	10. 657	10. 647	. 010	90	14. 501	14. 999	. 002
26	10. 657	10. 647	. 010	91	14. 501	14. 999	. 002
28	10. 657	10. 647	. 010	92	14. 501	14. 999	. 002
30	10. 657	10. 647	. 010	93	14. 502	14. 500	. 002
32	10. 657	10. 647	. 010	94	14. 501	14. 500	. 001
34	10. 657	10. 647	. 010	95	14. 501	14. 500	. 001
36	10. 657	10. 647	. 010	96	14. 501	14. 500	. 001
38	10. 657	10. 647	. 010	97	14. 502	14. 500	. 002
40	10. 657	10. 647	. 010	98	14. 501	14. 500	. 001
42	10. 656	10. 647	. 009	99	14. 501	14. 500	. 001
44	10. 656	10. 647	. 009	100	14. 501	14. 500	. 001
46	10. 656	10. 647	. 009	101	14. 501	14. 500	. 001
48	10. 657	10. 647	. 010	102	14. 501	14. 500	. 001
50	10. 657	10. 647	. 010	103	14. 501	14. 500	. 001
52	10. 657	10. 647	. 010	104	14. 501	14. 500	. 001
54	10. 657	10. 647	. 010	105	14. 501	14. 500	. 001
56	10. 657	10. 648	. 009	106	14. 501	14. 500	. 001
58	10. 657	10, 648	. 009	107	14. 502	14. 500	. 002
60	10. 157	10. 648	. 009	108	14. 502	14. 500	. 002
62	10. 657	10. 648	. 009	109	14. 502	14. 500	. 002
64	10. 656	10. 648	. 008	110	14. 502	14. 500	. 002
66	10. 656	10. 648	. 008	111	14. 501	14. 500	. 001
68	10. 656	10. 648	. 008	112	14. 501	14. 500	. 001
70	11. 503	11. 488	. 015	113	14. 502	14. 500	. 002
71	11. 503	11. 488	. 015	114	14. 501	14. 500	. 001
72	11. 504	11. 490	. 014	115	14. 501	14. 500	. 001
73	11. 504	11. 490	. 014	116	14. 501	14. 500	. 001
74	11. 504	11. 490	. 014	117	14. 501	14. 500	. 001
75	11. 504	11. 490	. 014	118	14. 501	14. 500	. 001
76	11. 504	11. 490	. 014	119	14. 501	14. 500	. 001
77	11. 504	11. 490	. 014	120	14. 501	14. 500	. 001
80	14. 501	14. 999	. 002	121	14. 501	14. 500	. 001

8 INCH M. L. CHAMBERED RIFLE.



LEGEND.

Charge	55· lbs
Projectile	180· "
Length of Bore (including chamber)	116·98 ins.
Diam of Chamber	9 "
Length "	28·017 "
Velocity (muzzle)	1641 feet
Total muzzle energy	3357· ft-tons.
Penetration at muzzle	14·09 ins

APPENDIX 8e.

EXPERIMENTAL CANNON POWDERS.

PROGRESS REPORT.

Progressive powder.—This powder, made in imitation of the Fossano progressive powder, was described in the progress report published in the Report of the Chief of Ordnance for last year.

Lot "I. E.," of density 1.756 and granulation 17 to the pound, the grains being approximatively one-inch cubes, was tested in June, 1880, in the 10-inch rifle. The results obtained were not deemed satisfactory. The powder makers, indeed, expressed a doubt as to the satisfactory behavior of this powder, since, being for them a novel mode of manufacture, considerable difficulty was experienced in obtaining a uniform mixture of the grains and the mealed powder, and in giving to the resulting mass the required mean density. They would probably meet with better success in a second trial. The results obtained with the largest charges employed were as follows:

Progressive powder.

Gun.	Weight of charge.	Weight of shot.	Velocity.	Pressure.
	Pounds.	*Pounds.*	*Feet.*	*Pounds.*
10-inch rifle	70	398	1, 272	30, 000
Do	80	398	1, 337	53, 000

The results obtained with like charges of Du Pont's hexagonal powder, of density 1.785 and granulation 67, I here insert for comparison:

Hexagonal (F. P. B.) powder.

Gun.	Weight of charge.	Weight of shot.	Velocity.	Pressure.
	Pounds.	*Pounds.*	*Feet.*	*Pounds.*
10-inch rifle	70	400	1, 381	22, 600
Do	80	400	1, 445	23, 500

Hexagonal powder.—Lot "I. J.": density. 1.78; granulation, 30 to the pound. This powder was manufactured in 1880 for the heavier calibers, as the 11 and 12 inch rifles. So far only two light charges have been fired, and these from the 12.25-inch rifle.

Sphero-hexagonal powder.—This powder, of density 1.728, and granulation 123 to the pound, described in the progress report of last year, and employed with the 3.17-inch chambered rifle has since been tested in the 4.5-inch service siege gun. The results obtained were very superior

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to those obtained with the "H. D., No. 4," of irregular granulation, as will appear from the following table:

Kind of powder.	Gun.	Weight of charge.	Weight of shot.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Ft.*	*Lbs.*
H. D. No. 4. D = 1.776; Gr. = 3,038	4″.5 siege rifle.	7	35	1,411	31,000
Sphero-hexagonal (I. B.) D = 1.728; Gr. = 123	Do.	7	35	1,424	21,500
Do		8	35	1,530	26,166

This powder was deemed so satisfactory, that it was adopted as standard for the 4.5-inch rifle; and, under authority from the Chief of Ordnance, the Constructor of Ordnance was authorized to purchase a quantity for employment with that gun, part of which was sent to the Military Academy at West Point, and part to the Artillery School at Fort Monroe, for use in target practice.

The following results were obtained in the proof of this new lot:

Gun.	Kind of powder.	Weight of charge.	Weight of shot.	Velocity.	Pressure.
		Lbs.	*Lbs.*	*Feet.*	*Lbs.*
4″.5 siege rifle	Sphero-hexagonal (I. B. B.). D = 1.728; Gr. = 123.	7	35	1,476	27,500
		7.5	35	1,539	30,000
		8	35	1,575	31,000
				1,567	28,000
				1,583	34,000

The first set of results was obtained with sphero-hexagonal powder which had been on hand for about one year.

Field-gun powders, 3.5-inch muzzle-loading rifle.—The I. A. powder, density 1.75 and granulation 2200, irregular grains, tested in the 3-inch breech-loading rifle, and described in last year's report, was thought to be rather slow burning for that piece; a trial of it was therefore made in the 3.5-inch rifle. The length of this gun is only 18.5 calibers, and being heavy and very strong, a pressure even of 50,000 pounds should not be deemed objectionable if accompanied by a good velocity.

Owing to some variations in the size of the cartridge bags, purposely introduced, but which greatly affected the velocity and pressure, the results obtained were various; the general behavior, however, of the powder was fair, as will appear from the following extract from the firing-record:

Gun.	Powder. Kind.	Powder. Weight.		Diameter of cartridge.	Weight of shot.		Velocity at 75 feet from muzzle.	Pressure.
		Lbs.	*Ozs.*	*In.*	*Lbs.*	*Ozs.*	*Feet.*	*Lbs.*
3.5-inch steel-bronze rifle.	I. A. D. = 1.750; Gr. = 2.200.	3	......	3.42	16	8	1,359	36,250
		3	8	......	16	8	1,453	50,000
		3	8	3.10	16	8	1,303	20,250
		4	......	......	16	8	1,401	29,500

3.18-*inch breech-loading chambered rifle.*—The Messrs. Du Pont were instructed to manufacture a sample of powder for trial with this gun, keeping the granulation the same as in the I. A. powder, viz, 2,200 to the pound, but lowering the density to 1.725. This powder was tested in May, 1880, with the following results:

Gun.	Powder. Kind.	Powder. Weight. Lbs.	Powder. Weight. Ozs.	Weight of projectile. Lbs.	Velocity at 89 feet from muzzle. Feet.	Pressure per square inch of bore. Lbs.
3.18-inch breech-loading chambered rifle.	I. K. D=1.725; Gr.=2,200, irregular granulation.	2	......	12	1,221	18,000
		2	.....	12	1,208	16,000
		2	......	12	1,198	16,000
		2	......	12	1,193	15,000
		2	8	12	1,363	24,000
		2	8	12	1,354	23,500
		2	8	12	1,377	26,000
		2	8	12	1,371	26,500
		3	.....	12	1,518	....

The capacity of the chamber was not sufficient to admit of the use of the pressure-gauge with a charge of 3 pounds, and the pressure was not ascertained with that weight of charge. For testing powder in this gun, it is proposed to fit a pressure-gauge into the face of the breech-block. The I. A. powder, density 1.75 and granulation 2,200, tested in this same gun, gave with a charge of 3 pounds and a projectile of 12 pounds, a velocity of 1,468 feet, at 93 feet from the muzzle of the gun; which shows a gain of nearly 50 feet for the I. K. powder.

NOTE.—The anomalous results obtained from the 8-inch rifle with the samples of H. B. and H. C. of sphero-hexagonal powder, referred to in the Progress Report on Experimental Powders last year (Report of Chief of Ordnance 1879, page 8), were due, as it has since been ascertained, to a departure from the standard proportions of ingredients in the manufacture of these samples; more niter being employed than is prescribed for the service powder, or was employed in the manufacture of the sample H. A. sphero-hexagonal powder.

CHAS. S. SMITH,
Captain of Ordnance.

APPENDIX 8 *f*.

TESTS OF BAR IRON USED IN THE FABRICATON OF WROUGHT-IRON TUBES FOR CONVERTED RIFLES.

In the construction of the first 8-inch converted rifles the wrought-iron tubes were made in England and the tests to which the bar iron used was subjected were those usual at the works of Sir William Armstrong, where the tubes were made. The specimens, taken with the fiber, were 2 inches in length between shoulders, and about 0.580 inch in diameter.

The results obtained from numerous specimens were approximately as follows:

	Pounds.
Tensile strength per square inch	50,000
Elastic limit per square inch	25,000

Extension per inch at rupture, 0″ .30.

When the fabrication of the tubes was first undertaken by the West Point foundry, it was prescribed in the contract that the bar iron should equal in all respects that used in the imported tubes; consequently it must have the same welding and physical properties, and be equally free from excess of cinder. The Ulster Iron Works undertook to furnish the West Point foundry with such bar iron, and, by dint of perseverance and the utmost care, have up to the present time produced a material of remarkable uniformity, which in all respects compares favorably with, and in some respects certainly surpasses, the English iron it at first aimed only to imitate.

In the report of the Chief of Ordnance for 1877 Capt. C. S. Smith describes the mode of manufacture of the iron and gives comparisons between it and the English iron as regards physical and chemical properties.

The standard at first established has been closely adhered to since; though in 1877 the length of specimens between shoulders was increased from 2 to 3 inches to adapt them to the device then adopted for measuring extensions and restorations. The method of proceeding has been as follows:

On receipt of the first lot of iron, two specimens are taken from sample bars of each size of the two grades of iron used.* These specimens are tested in the machine at the ordnance agency, not only for tensile strength, elasticity, and ultimate extension, but for gradual extensions, restorations, and permanent set; and if the iron prove satisfactory it is accepted, and the founders authorized to proceed with the work.

As subsequent lots arrive similar specimens are taken of each size of the two grades of iron as before, and tested in the machine at the foundry for tensile strength and ultimate extension. The following summary of the tests to which this iron has been subjected since January

* The two grades, denominated A and B, are used, respectively, for inner and outer tubes; their properties are almost identical, but the former, from additional working, contains less cinder.

1879, shows the degree of uniformity which has been attained in its manufacture:

No. of specimen.	Size of bar.	Where tested.	Specimens. Diameter.	Specimens. Length.	Tensile strength, pounds per square inch.	Elastic limit, pounds per square inch.	Extension per inch at rupture.	Remarks
			Inch.	Inches.			Inch.	
1	2¼″ square	Ordnance agency	0.564	3.00	49,850	25,000	0.291	A iron.
2	2¼″ square	do	0.564	3.00	47,500	28,000	0.3106	Do.
3	2¼″ square	do	0.564	3.00	46,500	25,000	0.2833	Do.
4	4″ by 3″.35	W. P. F	0.564	2.00	47,552	....	0.31	Do.
5	4″ by 3″.35	do	0.564	2.00	47,304	....	0.29	Do.
6	2¼″ square	do	0.564	3.00	50,493	....	0.274	Do.
7	2¾″ square	Ordnance agency	0.564	3.00	49,000	25,000	0.301	Do.
8	3″ square	do	0.564	3.00	48,000	24,000	0.285	Do.
9	4″ by 3″.35	W. P. F	0.564	3.00	50,624	....	0.267	Do.
10	2¼″ square	do	0.564	3.00	50,420	....	0.28	Do.
11	2¼″ square	do	0.564	3.00	51,220	....	0.232	Do.
12	2½″ square	Ordnance agency	0.564	3.00	49,000	29,000	0.3127	Do.
13	2½″ square	do	0.564	3.00	49,000	30,000	0.3097	Do.
14	2¼″ square	do	0.564	3.00	48,377	27,015	0.2713	B iron.
15	2¼″ square	do	0.564	3.00	48,500	26,000	0.299	Do.
16	4″ by 3″.35	do	0.564	3.00	45,600	23,000	0.174	Do.
17	4″ by 3″.35	do	0.564	3.00	44,500	22,000	0.266	Do.
18	4″ by 3″.35	do	0.564	3.00	49,500	21,000	0.296	Do.
19	4″ by 3″.35	do	0.564	3.00	49,500	25,000	0.268	Do.
20	2¼″ square	W. P. F	0.564	3.00	50,626	....	0.327	Do.
21	5⅛″ square	do	0.564	3.00	48,236	....	0.22	Do.
22	5⅛″ square	do	0.564	3.00	51,220	....	0.282	Do.
23	2¼″ square	do	0.564	3.00	51,948	....	0.283	Do.
24	4″ by 3″.35	do	0.564	3.00	51,040	....	0.290	Do.
25	4″ by 3″.35	do	0.564	3.00	51,757	....	0.270	Do.
26	2½″ square	Ordnance agency	0.564	3.00	48,000	23,000	0.293	Do.
27	2½″ square	do	0.564	3.00	48,000	26,000	0.289	Do.
28	2⅝″ square	do	0.564	3.00	51,000	25,000	0.320	A iron.
29	2½″ square	do	0.564	3.00	50,000	27,000	0.303	Do.
30	4″ by 3″.35	do	0.564	3.00	48,000	25,000	0.287	Do.
31	2⅜″ square	do	0.564	3.00	49,000	27,000	0.309	Do.
32	2½″ square	do	0.564	3.00	49,000	27,000	0.299	Do.
33	4″ by 3″.35	do	0.564	3.00	48,000	25,000	0.289	Do.
34	4″ by 3″.35	do	0.564	3.00	50,000	26,000	0.245	Do.
35	2¾″ square	do	0.564	3.00	49,000	23,000	0.309	Do.
36	3″ square	do	0.564	3.00	49,000	25,000	0.306	Do.
37	2¾″ square	do	0.564	3.00	50,000	26,000	0.316	Do.
38	5¼″ square	do	0.564	3.00	49,000	23,000	0.277	B iron.
39	2¾″ square	do	0.564	3.00	51,000	26,000	0.284	Do.
40	2¾″ square	do	0.564	3.00	53,000	27,000	0.287	Do.

Specinens 28 to 40, inclusive, were taken from bars now being used under present contracts.

In order to determine to what extent these tests of specimens indicate the true physical properties of the bar-iron itself, two bars of tube iron were obtained last January from the Ulster Iron Works for the purpose of having them broken in the machine at Watertown Arsenal.

These bars of A and B quality respectively, were 2.5 inches square in cross section and 67 inches long. From the ends of each were taken the usual specimens, which were tested at the Ordnance Agency, while the remainder of the bars were sent to Watertown Arsenal.

The following are the results obtained:

Subject of measurement.	Watertown Arsenal.	Ordnance agency* mean of the results.
A Iron.		
Length between shoulders .... inches..	21. 876	3. 00
Cross section .... do....	2.5 x 2.13	0. 570
Area .... square inches..	5. 325	0. 2547
Tensile strength per square inch .... pounds..	51. 940	49. 000
Elastic limit per square inch .... do....	20. 000	29. 500
Extension per inch at rupture .... inches..	0. 273	0. 3112
B Iron.		
Length between shoulders .... inches..	21. 68	3. 00
Cross section .... do....	2.55 x 2.13	0. 569
Area .... square inches..	5. 4315	0. 2552
Tensile strength per square inch .... pounds..	56. 760	48. 000
Elastic limit per square inch .... do....	....	24. 500
Extension per inch at rupture .... inches..	0. 2477	0. 2910

* Specimens 12, 13, 26, and 27 preceding page.

It was expected that in spite of the greater length between shoulders the iron in the bar might exhibit a somewhat greater tensile strength per square inch than would be shown in the specimens, from the fact that on two sides of the bar the skin was not removed. The difference between the extensions in the two cases is also no greater than was expected from the difference in lengths. But there are three features shown in the above table which are inconsistent with the results which were anticipated.

1st. The elastic limit in the case of the A iron is very much lower in the bar than in the specimens.

2d. The two experiments disagree as to the comparative strength of the two grades of iron.

3d. The difference in strength between the B iron in the bar and in the specimens, is much greater than the corresponding difference in the case of the A iron.

As regards the first of these:

The first permanent set of the A iron, as determined at Watertown Arsenal, is 0″.001, which becomes 0″.00012 when reduced to the length of the specimens (3″.00). So slight a change could not be read with the vernier used on the machine at the Ordnance Agency during these experiments as its least reading is only 0″.001.

The permanent set commenced to increase rapidly after 27,000 pounds to the square inch, and with the specimens immediately after passing the recorded elastic limit (29,000 pounds to the square inch).

It is probable, therefore, that the elastic limit as determined for the specimens by the machine at the Ordnance Agency is considerably too high, which would at least moderate the dissimilarity as regards this property between the iron in the bar and in the specimens.

As regards the two other discrepancies mentioned, in all probability they are explained by the fact noted in Colonel Laidley's report of the experiments at Watertown Arsenal; "at 268,600 pounds the packing of pump gave way when the strain was taken off and specimen stood twenty hours.

It seems, therefore, that the specimens ordinarily tested before accepting tube iron for use in gun constructions, fairly represent the bars from which they are taken.

C. W. WHIPPLE,
Lieutenant of Ordnance.

REPORTS OF THE ORDNANCE BOARD.

LIEUT. COLS. S. CRISPIN AND T. G. BAYLOR AND MAJ. C. COMLY, ORDNANCE DEPARTMENT.

APPENDIX 9.

FIELD, SIEGE, AND SEA-COAST CANNON.

(Sixty-five plates.)

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PLATES.

ORDNANCE.

The term ordnance includes cannon of all kinds fired from *carriages*, *slides*, *beds*, *tripods*, &c.

Classification: Cannon are classified according to their nature, as *guns*, *howitzers*, *mortars*, and *machine-guns*, and according to their uses, as *field*, *mountain*, *siege*, and *sea-coast*.

Guns are further classified as to their construction, as *smooth-bore* and *rifle;* as *muzzle-loading* and *breech-loading;* and as *cast* and *built up* cannon.

All ordnance for *land service* is made by private contractors, under the direction of officers of the Ordnance Department.

The kinds and calibers, standard, are as follows:

	Model.
Field guns:	
3-inch (rifled) wrought iron	1861
3.5-inch (rifled) wrought iron	1868
4.62-inch (smooth-bore) bronze	1857
1.45-inch (rifled) steel Hotchkiss revolving gun.	
1.65-inch (rifled) steel Hotchkiss.	
1-inch Gatling guns.	
0.5-inch Gatling guns.	
0.45-inch Gatling guns.	
Siege, garrison, and sea-coast guns:	
4.5-inch rifled, muzzle-loading, cast iron	1861
8-inch rifled, muzzle-loading, cast iron, converted	1871 to 1874
10-inch rifled, muzzle-loading, cast iron, converted	1871 to 1874
11-inch rifled, muzzle-loading, cast iron, converted	1871 to 1874
12-inch rifled, muzzle-loading, cast iron, lined with wrought-iron tube	1871 to 1874
8-inch rifled, breech-loading, cast iron, converted	1871 to 1874
10-inch smooth-bore cast-iron	1861
15-inch smooth-bore, cast-iron	1861, 1874
20-inch smooth-bore, cast-iron	1861
Howitzers:	
Mountain, 4.62-inch smooth-bore, bronze	1861
Siege and garrison, 8-inch smooth-bore, cast-iron	1861
Mortars:	
Siege, 8-inch smooth-bore, cast iron	1861
Sea-coast 10-inch smooth-bore, cast iron	1861
Sea-coast 13-inch smooth-bore, cast iron	1861
Coehorn 5.62-inch smooth-bore, bronze	1841

Rifled howitzers and mortars, and guns with chambers for large charges, are now under consideration.

Rifled breech-loading field guns are also now under trial.

For the present, until superior armament can be provided, guns of obsolete patterns and kinds are retained in service. (See tables.)

Standard guns, howitzers, and mortars take their denomination from the caliber in inches.

DEFINITIONS.

Cascabel.—The knob on the end of the breech of a gun; it is composed of the *knob* and the *neck*; sometimes the *fillet*.

Breech.—The mass of solid metal behind the bottom of the bore.

Base of the breech.—The rear surface of the breech.

Base-line—A line traced around the gun in rear of the vent.

Base-ring.—A projecting band of metal adjoining the base of the breech and connected with the body of the gun by a concave molding,

Reinforce.—The thickest part of the body of the gun in front of the base-ring or line; if there is more than one reinforce, that which is next to the base ring is called the *first reinforce*, the other the *second reinforce.*

Chase.—The conical part of the gun in front of the reinforce.

Astragal and *fillets.*—The molding at the front end of the chase.

Chase-ring.—A band at the front end of the chase.

Neck.—The smallest part of the piece in front of the chase.

Swell of the muzzle.—The largest part of the gun in front of the neck.

Muzzle-band.—A band which takes the place of the swell of the muzzle in some guns.

Face of the piece.—The plane terminating the gun at the muzzle.

Trunnions.—Two cylinders near the center of gravity of the gun, by which it is supported on its carriage. The axis of the trunnions are perpendicular to the axis of the bore, and in the same plane with that axis.

Rimbase.—The shoulder at the base of the trunnion.

Bore.—All the part bored out.

Chamber.—The part of the bore, joining and terminating the cylindrical part. In breech-loading guns, the seat of the charge and projectile.

Gomer chamber.—A conical chamber which is joined to the cylinder of the bore by a portion of a spherical surface.

True windage.—The difference between the true diameter of the bore and the largest diameter of the projectile.

Natural line of sight.—A line drawn in a vertical plane through the axis of the piece, from the highest point of the maximum diameter to the highest point of the muzzle, or to the top of the sight, if there be one.

Natural angle of sight.—The angle which the natural line of sight makes with the axis of the piece.

Dispart.—The difference of the semi-diameters of the maximum diameter and the muzzle. It is therefore the tangent of the natural angle of sight to a radius equal to the distance from the maximum diameter to the highest point of the muzzle.

Preponderance.—The excess of weight of the part in rear of the trunnions over that in front; it is measured by the weight which the breech bears on a balance, the point of support resting at the base-line or at the bottom of the ratchet, the gun being suspended freely on the axis of the trunnions.

Ear.—A lug of metal cast on some mortars; it is attached to a clevis by a bolt and constitutes a handle.

NOMENCLATURE.

(Guns of the model of 1861 and 1874.)

PARTS.—The *bore:* a cylinder terminated by a *semi-ellipsoid*, the *chamfer.*

The *breech:* the *cascabel*, the *knob*, the *neck.*

The *body of the gun:* the *reinforce*, the *chase*, the *muzzle*, the *face*, the *trunnions*, the *rimbases.*

For rifled guns: *vent-piece*, wrought-copper, screwed in.

RODMAN GUNS.—Add to the above the *ratchet;* the *sight-piece.*

MORTARS.—Omit the *cascabel*, the *knob*, the *neck*, and add the *ratchet.* For the *sea-coast mortars* add the *ear.*

Guns and mortars have their *vents* in planes parallel to the plane through the axis of the bore and perpendicular to the axis of the trun-

nions. The vents are at right angles to the elements of the cylinder of the bore; the one on the right of the axis is not bored entirely through to the bore by one inch. The vent of the siege and field pieces is at right angles to the axis, and in the vertical plane passing through it.

For converted guns.—The bore is a cylinder, terminated by a *frustum of cone.*

Trunnion-rings, made eccentric, are placed on the trunnions to compensate for the muzzle preponderance occasioned by lining the casing and reducing the diameter of the bore.

BREECH-LOADING GUNS.—The *bore* is a cylinder terminated by a *chamber* for the charge and projectile. In all rifled guns, the rifling terminates gradually at the seat of the charge, and in breech-loading guns in front of the bearing part of the projectile.

TABLE I.—*Principal dimensions and weights of standard ord-*

Nature of ordnance.	Material.	Caliber.	Weight.	Preponderance.	Windage.	Lengths. Of entire piece.	Lengths. Nominal, without cascabel.	Lengths. Of bore, in inches.	Lengths. Of bore, in calibers.
SEA-COAST PIECES.									
Guns.		*In.*	*Pounds.*	*Lbs*		*Inches.*			
12-inch rifle (model 1874)	Cast iron, wro'ght-iron lined.	12	89, 600	0	0. 09	262. 8	......	227	18. 92
12-inch rifle (model 1870)	Cast iron	12	82, 878	0	0. 09	240	......	209	17. 41
10-inch rifle	Cast iron, wro'ght-iron lined.	10	40, 681	0	0. 08	180	......	158. 5	15. 85
8-inch rifle (converted)	....do	8	16, 160	0	0. 05	136. 66	......	117. 25	14. 66
20-inch smooth bore	Cast iron	20	115, 200	0	0. 19	243. 5	......	210	10. 50
15-inch smooth bore (model 1874).	....do	15	70, 778	....	0. 15	215	......	190	12. 66
15-inch smooth bore (model 1861).	....do	15	49, 099	0	0. 15	190	......	165	11
13-inch smooth bore	... do	13	38, 500	0	0. 14	177. 61	......	155. 85	11. 98
Mortars.									
15-inch smooth bore	Cast iron	15	33, 675	0	0. 13	75	......	51. 25	3. 42
13-inch smooth bore	....do	13	17, 250	0	0. 13	56. 5	......	35	2. 69
SIEGE PIECES.									
Guns.									
4.5-inch, rifled	Cast iron	4. 5	3, 450	300	0. 05	133	127. 3	120	26. 67
Howitzers.									
8-inch smooth bore	Cast iron	8	2, 600	380	0. 12	60	54. 5	46. 5	5. 81
Mortars.									
10-inch smooth bore	Cast iron	10	1, 900	0	0. 13	29. 25	......	20. 5	2. 05
8-inch smooth bore	....do	8	1, 050	0	0. 12	23. 25	......	16	2
5.82-inch smooth bore, Coehorn.	Bronze	5. 82	164	0	0. 14	16. 32	......	13. 07	2. 24
FIELD PIECES.									
Guns.									
4.62-inch (12-pounder) smooth bore.	Bronze	4. 62	1, 230	105	0. 10	72. 55	67. 6	63. 6	13. 76
3.5-inch rifle	Wrought iron	3. 5	1, 156	0	0. 05	73. 84	69. 375	65	18. 57
3-inch rifle	....do	3	830	40	0. 05	72. 65	69. 2	65	21. 66
1.65-inch rifle (breech-loader), mountain.	Steel	1. 65	116. 85	....	0	45. 86	......	41. 35	25. 33
1.45-inch cannon revolver, Hotchkiss.	....do	1. 457	1, 212. 605	....	0	66. 75	......	50. 39	34. 75
0.45-inch Gatling	....	0. 45	195. 5	....	0	49. 7	......	32	71. 1
0.45-inch Gatling (cavalry)	....	0. 45	....	....	0	....	......	....	......
Howitzers.									
4.62-inch smooth bore, mountain.	Bronze	4. 62	220	30	0. 10	37. 21	33. 51	30. 91	6. 69

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Lengths.			Distances.					Diameters.				
Of rifled part of bore.	Of semi-axis of ellipse, bottom of bore.	Of trunnions.	From base line to face of muzzle.	From maximum diameter to face of muzzle.	From axis of trunnions to face of muzzle.	From axis of trunnions to base of breech.	Between rimbases.	At base line.	At muzzle.	Maximum.	Of trunnions.	Of rimbases.
Inches.	*Inches.*	*In.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*In.*	*In.*
198	....	6.3	218	218	167.6	95.2	55.1	55	27.50	55	15	17
198	9	5	200	200	149.72	90.28	54.1	54	28	54	15	17
148	7.5	4.5	149.34	149.34	115.96	64.04	45.1	45	21	45	13	15
107.25	....	3.25	110	110	87.76	48.9	32.1	32	16.2	32	10	11.5
....	15	6.5	195	195	152.7	90.8	64.2	64	34	64	18	20.5
....	8	4.5	177	177	139.35	75.65	51.1	51	24.7	51	15	17
....	9	4.5	155	155	120.45	69.55	48.1	48	25	48	15	17
....	9.75	4.5	150.19	150.19	115.21	62.40	45.1	45	21	45	13	15
....	11.25	5	....	35	33.5	41.5	52.2	....	50	52	18	20
....	9	4.5	....	....	26	30.5	43.4	....	43	43	15	17
....	3.375	4	121	110	78.35	48.95	15	15.6	9	16	5.3	6.3
....	6	5	50	....	26.09	28.41	18	17.5	15	17.5	5.82	7
....	7.5	3.25	18	....	13	16.25	20.4	20	20	20	12	13.5
....	6	3.25	14	....	10	13.25	16.4	16	16	16	10	11.5
....	....	2.5	....	....	14.945	0.755	7.5	....	7.65	8.65	2.75	2
....	....	3.25	66	....	38.5	29.1	11.5	11	7.5	11	4.2	6.2
60.375	2.625	3.25	....	62	42.684	27.69	11.5	....	6.7	11.2	4.2	5.7
60.25	2.25	2.8	66.25	50	41.415	27.785	9.5	9.27	6	9.7	3.67	4.67
....	....	1.77	....	....	27.39	13.46	4.72	....	2.55	5.03	1.77	......
....	....	......	....	....	....	....	....	....	....	....	......	......
....	....	......	....	....	....	....	....	....	5.82	6.56	......	......
....	....	......	....	....	....	....	....	....	....	....	......	......
....	....	2.25	....	26.91	16.56	16.75	6.9	....	6.9	7.6	2.7	4.2

TABLE I.—*Principal dimensions and weights of standard ordnance,*

Nature of ordnance.	Rifling.							
	Twist, in feet.	Number of grooves.	Width of grooves.	Depth of grooves.	Width of lands.	Radius of fillet at bottom.	Radius of bevel at top.	Length of terminal bevels of grooves.
			Inches.	*Inches.*	*Inches.*	*In.*	*In.*	*In.*
SEA-COAST PIECES.								
Guns.								
12-inch rifle (model 1874)	70	21	0. 8976	0. 09	0. 8976	0. 05	0. 02	2
12-inch rifle (model 1870)	80	21	1. 045	0. 1	0. 75	0. 05	0. 02	2
10-inch rifle	50	17	0. 924	0. 08	0. 924	0. 02	0. 01	......
8-inch rifle (converted)	40	15	0. 8377	0. 075	0. 8377	0. 02	0. 01	......
20-inch smooth bore	......	......	......	......	......	......	......	......
15-inch smooth bore (model 1874)	......	......	......	......	......	......	......	......
15-inch smooth bore (model 1861)	......	......	......	......	......	......	......	......
13-inch smooth bore	......	......	......	......	......	......	......	......
Mortars.								
15-inch smooth bore	......	......	......	......	......	......	......	......
13-inch smooth bore	......	......	......	......	......	......	......	......
SIEGE PIECES.								
Guns.								
4.5-inch rifled	15	9	0. 97	0. 075	0. 6	......	......	......
Howitzers.								
8-inch smooth bore	......	......	......	......	......	......	......	......
Mortars.								
10-inch smooth bore	......	......	......	......	......	......	......	......
8-inch smooth bore	......	......	......	......	......	......	......	......
5.82-inch smooth bore, Coehorn	......	......	......	......	......	......	......	......
FIELD PIECES.								
Guns.								
4.62-inch (12-pounder) smooth bore	......	......	......	......	......	......	......	......
3.5-inch rifle	12	7	1. 07	0. 075	0. 5	0. 04	0. 02	2
3-inch rifle	10	7	0. 84	0. 075	0. 5	......	......	1. 5
1.65-inch rifle (breech-loader) mountain	4. 1	10	0. 362	0. 012	0. 157	......	......	......
1.45-inch cannon revolver, Hotchkiss	4. 1	6	0. 314	0. 019	0. 447	......	......	......
0.45-inch Gatling	1. 16	......	0. 1413	0. 010	0. 1413	......	......	......
0.45 inch Gatling (cavalry)	......	......	......	......	......	......	......	......
Howitzers.								
4.62-inch smooth bore, mountain	......	......	......	......	......	......	......	......

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Chambering.			Venting.								
Length of chamber.	Diameter at top.	Diameter at bottom.	Material of vent bush.	Diameter of vent bush.	Diameter of vent.	Distance from bottom of bore.	Distance from vertical plane through axis of bore.	Length of threaded portion.	Pitch of thread.	Height of head.	Diameter of head.
In.	*In.*	*In.*		*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*In.*
......	......	......	Copper	1	0.2	9.5	3.0	5	0.125	0.75	1.75
......	......	......	....do	1	.2	4	3	5	0.125	0.75	1.75
......	......	......	....do	1	.2	3	2	3.75	0.125	0.75	1.75
......	......	......	....do	1	.2	3.5	2.5	3.75	0.125	0.75	1.75
......	......	......	....do	1	.2	7.5	4	3.75	0.125	0.75	1.75
......	......	......	....do	1	......	......	......	3.75	0.125	0.75	1.75
......	......	......	....do	1	0.2	4	3	3.75	0.125	0.75	1.75
......	......	......	....do	1	.2	3	......	3.75	0.125	0.75	1.75
......	......	......	Copper	1	0.2	3	3.5	......	......	......	......
......	......	......	....do	1	.2	3	2	......	......	......	......
......	......	......	Copper	0.85	0.2	1.75	0	2.5	0.10	0.62	1.25
......	......	......	Copper	1	0.2	2	0	......	......	......	......
......	......	......	Copper	1	0.2	2	1.5	......	......	......	......
......	......	......	....do	1	.2	1	1.5	......	......	......	......
4.25	3	2	... do	1	.2	.4	0	......	......	......	......
......	......	......	Copper	1	0.2	1.15	0	......	......	......	......
......	......	......	....do	1	.2	1.5	0	......	......	......	......
......	......	......	....do	1	.2	1.25	0	......	......	......	......
7.75	1.65	1.85	....do	0.47	......	0	......	0.47	......	0.98	0.7
......	......	......	....do	......	......	......	......	......	......	......	......
......	......	......	....do	......	......	......	......	......	......	......	......
......	......	......	....do	......	......	......	......	......	......	......	......
......	......	......	Copper	......	......	0.4	0	......	......	......	......

TABLE II.—*Ordnance and ammunition*

[Standard and

Nature of ordnance.	Material.	Weight.	Preponderance.
SEA-COAST PIECES.			
Guns.		*Pounds.*	*Lbs.*
12-inch rifle (model 1874)	Cast iron, wrought-iron lined	89, 600	0
12-inch rifle (model 1870)	......do	82, 878	0
10-inch rifle	......do	40, 681	0
8-inch rifle (converted)	Cast iron, with wrought iron tubes.	16, 160	0
10-inch rifle (Parrott, 300-pounder)	Cast iron, with wrought iron jacket.	26, 500	0
8-inch rifle (Parrott, 200-pounder)	......do	16, 300	0
6.4-inch rifle (Parrott, 100-pounder)	......do	9, 700	0
7-inch rifle (banded, 42-pounder)	Cast iron	....	......
6.4-inch rifle (banded, 32-pounder)	......do	....	......
20-inch smooth bore	......do	115, 200	0
15-inch smooth bore (model 1874)	......do	....	......
15-inch smooth bore (model 1861)	......do	49, 099	0
13-inch smooth bore	......do	38, 500	0
10-inch smooth bore	......do	15, 059	0
8-inch smooth bore	......do	8, 490	0
Mortars.			
15-inch smooth bore	Cast iron	33, 675	0
13-inch smooth bore	......do	17, 250	0
10-inch smooth bore	......do	7, 300	0
SIEGE PIECES.			
Guns.			
4.5 inch rifle	Cast iron	3, 450	300
4.2-inch rifle (Parrott, 30-pounder)	Cast iron, with wrought iron jacket.	4, 200	......
Howitzers.			
8-inch smooth bore	Cast iron	2, 600	380
5.82-inch smooth bore (flank defense)	......do	1, 476	70
Mortars.			
10-inch smooth bore	Cast iron	1, 900	......
8-inch smooth bore	......do	1, 050	......
5.82-inch smooth bore, Coehorn	Bronze	164	......
FIELD PIECES.			
Guns.			
3.5-inch rifle	Wrought iron	1, 156	0
3-inch rifle	......do	830	40
3-inch rifle (Parrott, 10-pounder)	Cast iron	890	......
1.65-inch rifle (breech-loader) mountain, Hotchkiss	Steel	116. 85	......
1.457-inch cannon revolver, Hotchkiss	......do	1, 212. 60	.....
4.62-inch (12-pounder) smooth bore	Bronze	1, 230	105
1-inch Gatling	Steel	1, 008	110
0.5-inch Gatling	......do	365	45
0.45-inch Gatling	......do	195. 5	......
Howitzers.			
6.4-inch smooth bore	Bronze	1, 920	160
4.62-inch smooth bore mountain	......do	220	30

of the United States land service.

retained calibers.]

Extreme length.	Maximum diameter.	Minimum diameter.	Length of bore in calibers.	Rifling. Number of grooves.	Width of grooves.	Depth of grooves.	Width of lands.	Twist in calibers.	Character of.
Inches.	*Inches.*	*Inches.*			*Inches.*	*Inches.*			
262.8	55	27.50	18.92	21	0.9163	0.09	0.9163	70	Uniform.
240	54	28	17.41	21	1.045	0.1	0.75	80	Do.
180	45	21	15.85	17	1.15	0.085	0.7	60	Do.
136.66	32	16.2	14.66	15	0.8377	0.075	0.8377	60	Do.
175.1	40	20	14.4	15	1.0472	0.1	1.0472	....	Increasing.
163	32	16.2	17	11	1.1424	0.1	1.1424	....	Do.
154.25	25.9	13	20.31	9	1.1170	0.1	1.1170	....	Do.
129.4	25.9	12.4	15.53	15	0.869	0.075	0.6	60	Uniform.
125.20	25.9	11.75	16.81	13	0.946	0.075	0.6	56.25	Do.
243.5	64	34	10.50	......	....	....	....	....	
....	....	....	12.66	......	....	....	....	....	
190	48	25	11	......	....	....	....	....	
177.6125	45	21	11.98	......	....	....	....	....	
136.66	32	16.2	12	......	....	....	....	....	
123.5	25.6	13.2	13.75	......	....	....	....	....	
75	52	50	3.42	......	....	....	....	....	
56.5	43	48	2.69	......	....	....	....	....	
49.25	30	30	3.25	......	....	....	....	....	
133	16	9	26.67	9	0.97	0.075	0.06	40	Uniform.
132.75	18.3	8.6	28.57	5	....	0.1	....	....	Increasing.
60	17.5	15	5.81	......	....	....	....	....	
69	13.8	11.7	9.96	......	....	....	....	....	
29.25	20	20	2.05	......	....	....	....	....	
23.25	16	16	2	......	....	....	....	....	
16.32	7.65	7.65	2.24	......	....	....	....	....	
73.84	11.2	6.7	18.57	7	1.07	0.075	0.5	41.143	Uniform.
72.65	9.7	6	21.66	7	.84	0.075	0.5	40	Do.
77.8	11.3	5.8	23.33	3	....	0.1	....	....	Increasing.
45.86	5.03	2.55	25.35	10	0.362	0.012	0.157	33.784	Uniform.
66.75	....	....	34.75	6	0.314	0.019	0.447	33.784	Do.
72.55	11	7.5	13.76	......	....	....	....	....	
68	6.8	....	3.3	6	0.2618	0.010	0.2618	72	Uniform.
60	6	....	6.4	6	0.1309	0.010	0.1309	84	Do.
49.7	6.56	5.80	71.11	5	0.1413	0.010	0.1413	48.88	Do.
82	13.8	10	11.09	......	....	....	....	....	
37.21	6.9	6.3	6.69	......	....	....	....	....	

TABLE II.—*Ordnance and ammunition of*

[Standard and

Nature of ordnance.	Windage.	Charge.	
		Kind of powder.	Weight, maximum.
SEA-COAST PIECES.			
Guns.	*Inches.*		*Pounds.*
12-inch rifle (model 1874)	0.09	Hexagonal	110
11-inch rifle (model 1870)	0.05	....do	100
10-inch rifle	0.05	....do	80
8-inch rifle (converted)	0.05	....do	35
10-inch rifle (Parrott, 300-pounder)	....	Cannon	25
8-inch rifle (Parrott, 200-pounder)	....	....do	16
6.4-inch rifle (Parrott, 100-pounder)	....	....do	10
7-inch rifle (banded, 42-pounder)	....	....	....
6.4-inch rifle (banded, 32-pounder)	....	....	....
20-inch smooth bore	0.13	Mammoth	200
15-inch smooth bore (model 1874)	0.13	....	....
15-inch smooth bore (model 1861)	0.13	Hexagonal	125
13-inch smooth bore	0.13	Mammoth No. 5	70
10-inch smooth bore	0.13	Cannon No. 5	25
8-inch smooth bore	0.13	Cannon	15
Mortars.			
15-inch smooth bore	0.13	Mortar	....
13-inch smooth bore	0.13	... do	20
10-inch smooth bore	0.13	....do	12
SIEGE PIECES.			
Guns.			
4.5-inch rifle	0.5	New mortar	7
4.2-inch rifle (Parrott, 30-pounder)	....	....do	....
Howitzers.			
8-inch smooth bore	0.12	Mortar	4
5.82-inch smooth bore (flank defense)	0.14	....do	2
Mortars.			
10-inch smooth bore	0.13	Mortar	4
8-inch smooth bore	0.12	....do	2.25
5.82-inch smooth bore, Coehorn	0.14	... do	0.5
FIELD PIECES.			
Guns.			
3.5-inch rifle	0.05	New mortar	3
3 inch rifle	0.05	....do	2
3-inch rifle (Parrott, 10-pounder)	....	....do	1
1.65-inch rifle (breech-loader) mountain, Hotchkiss	0	....	....
1.457-inch cannon revolver, Hotchkiss	....	....	1,851 grs.
4.62-inch (12-pounder) smooth bore	0.10	Mortar	2.5
1-inch Gatling	....	Musket	325 grs.
0.5-inch Gatling	....	....do	70 grs.
0.45-inch Gatling	....	....do	70 grs.
Howitzers.			
6 4-inch smooth bore	0.10	Mortar	3.25
4.62-inch smooth bore mountain	0.10	....do	0.5

* Except for machine-guns and the Hotchkiss mountain breech-loading gun, shot and shell for rifled
No special sabot, however, has as yet been adopted as standard. The Butler, Parrott, Arrick, and

the United States land service—Continued.

retained calibers.]

Projectiles.*			Ratio of weight—					
Shot.	Shell, empty.	Bursting charge.	Of charge to weight of projectile.	Of projectile to weight of piece.	Initial velocity.	Muzzle energy.	Elevation.	Range.
					Feet.	*Ft.-tons.*	° ″	*Yards.*
700			1 to 6.087	1 to 128	1,396	9,443		
600			1 to 6	1 to 136.16	1,310	7,182		
400	360		1 to 5	1 to 101.7	1,430	5,670		
180	150		1 to 5.14	1 to 89.77	1,414	2,510		
300	250		1 to 12	1 to 88.33			13 30	4,920
200	150		1 to 12.5	1 to 81.5			11 47	4,272
100	80 to 100		1 to 15	1 to 97	1,222 to 1,335		35 00	8,453
1,080	725		1 to 5.4	1 to 106.66			25 00	8,000
450	330	17						
450	330	17	1 to 3.6	1 to 109.10	1,735	9,449		
283 to 300	224	7	1 to 4.23	1 to 132.50	1,597	5,337		
128	100	3	1 to 5.12	1 to 117.64	1,500	1,996		
68	48	1.8	1 to 4.53	1 to 124.85				
	330			1 to 102.04				
	216	7	1 to 10.3	1 to 78.39			45 00	4,636
	101.67	2	1 to 8.47	1 to 71.80			45 00	4,536
35	25		1 to 5	1 to 103	1,420	503.2		
25 to 30	29			1 to 140	1,293		25 00	6,700
	45	1.8	1 to 11.5	1 to 57.77	1,070		12 30	2,280
	17	0.75	1 to 3.5	1 to 86.82			5 00	1,322
	88	3	1 to 22	1 to 21.59			45 00	2,064
	44	1.8	1 to 19.55	1 to 23.86			45 00	2,225
	17	0.75	1 to 34				45 00	1,200
16.75			1 to 5.58	1 to 69.01	1,314			
10	9.5		1 to 5	1 to 83	1,418			
10.5	9.75		1 to 10.5	1 to 84.76	1,232		20 00	5,000
	7,716 grs.	617 grs.	1 to 4.16	1 to 11.00	1,476			
12.3	8.34	.702	1 to 4.92	1 to 10	1,495		10 00	2,000
3,500 grs.								1,200
450 grs.					1,350		4 45	1,000
405 grs.								
Case, 30.75	23.03	1.4	1 to 9.46	1 to 62.43	1,182		15 00	2,344
Canister, 12.17	8.34	1.10	1 to 24.34	1 to 18.07			5 00	1,005

guns are fitted with an expanding sabot, to communicate to the projectile the rotation due to the rifling.
Dana all give good results.

TABLE III.—*Principal dimensions and weights of*

Nature of ordnance.	Material.	Caliber.	Weight.	Preponderance.	Windage.	Lengths. Of entire piece.
SEA-COAST PIECES.						
Guns.						
		In.	*Lbs.*	*Lbs*	*In.*	*In.*
10-inch rifle (Parrott, 300-pounder)	Cast iron with wrought-iron jacket.	10	26, 500	0	......	175. 1
8-inch rifle (Parrott, 200-pounder)	....do	8	16, 300	0	......	163
6.4-inch rifle (Parrott, 100-pounder)	....do	6. 4	9, 700	0	......	154. 25
7-inch rifle (banded, 42-pounder)	Cast iron	7. 018	....	....	......	129. 4
6.4-inch rifle (banded, 32-pounder)	....do	......	....	....	......	125. 205
10-inch smooth bore, Rodman	....do	10	15, 059	0	0. 13	136. 66
8-inch smooth bore, Rodman	....do	8	8, 490	0	0. 12	123. 5
Mortars.						
10-inch smooth bore	Cast iron	10	7, 300	0	0. 13	49. 25
SIEGE PIECES.						
Guns.						
4.2-inch rifle (Parrott, 30-pounder)	Cast iron with wrought-iron jacket.	4. 2	4, 200	....	......	132. 75
Howitzers.						
5.82-inch smooth bore, flank-defense	Cast iron	5. 82	1, 476	70	0. 14	69
FIELD PIECES.						
Guns.						
3-inch rifle (Parrott, 10-pounder)	Cast iron	3	890	....	......	77. 8
1-inch Gatling	Steel	1	1, 008	110	0	....
0.5-inch Gatling	....do	0. 5	365	45	0	....
Howitzers.						
6.4-inch smooth bore	Bronze	6. 4	1, 920	160	0. 15	82

retained ordnance, United States land service.

Lengths.					Distances.			Diameters.			Rifling.					Chambering.		
Nominal, without cascabel.	Of bore.	Of rifled part of bore.	Of semi-axis of ellipse, bottom of bore.	Of trunnions.	From axis of trunnions to face of muzzle.	Between rimbases.	From base line to face of muzzle.	At muzzle.	Maximum.	Of trunnions.	Twist.	Number of grooves.	Width of grooves.	Depth of grooves.	Width of lands.	Length of chamber.	Maximum diameter.	Minimum diameter.
In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*Ft.*	*In*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
166.25	144	.....	5 rad.	4.5	105	36	....	20	40	10	...	15	1.0472	0.1	1.0472	...	....	....
154.5	136	......	4 rad.	4.5	96	26	....	16.2	32	10	...	11	1.1424	0.1	1.1424	....	....	....
145.2	130	.....	3.2 rad.	5	91.8	22	....	13	25.9	8	...	9	1.1170	0.1	1.1170	....	....	....
120.7	109	106	....	6.5	70.491	22	....	12.4	25.9	7.018	35	15	0.869	0.075	0.6	....	....	....
117.205	107.59	104.59	....	6	68.595	21	....	11.75	25.9	6.41	30	13	0.946	0.075	0.6	....	....	....
......	120	......	7.5	3.25	87.76	32.1	110	16.2	32	10	...	...	......	.....	......	....	....	....
......	110	.....	6	3.25	79.83	25.7	101	13.2	25.6	8	...	...	......	.....	......	...	....	....
....	32.5	....	7.5	3.25	22	30.4	....	30	30	12	...	...	......	.....	......	...	....	....
128	120	......	2.1 rad.	2.75	82.15	16.8	....	8.6	18.3	5.3	...	5	1.319	0.1	1.1319	....	....	....
63	58	......	....	3.25	35	12.8	....	11.17	13.8	4.62	...	...	......	.....	......	4.75	4.62	4.62
74.65	70	......	1.5 rad.	2.8	47.1	9.5	....	5.8	11.32	3.67	...	3	1.5708	0.1	1.5708	...	....	....
....	33	......	....	....	......	....	....	......	6.8	......	6	6	......	0.01	......	....	....	....
....	32	......	......	....	......	....	....	......	6.0	......	3.6	6	......	0.01	......	....	....	....
76.2	71	......	....	3.5	41.99	12	....	11.2	13.8	4.62	...	...	......	.....	......	7	4.62	4.62

TABLE IV.—*Dimensions, &c., of obsolete*

Nature of ordnance.	Material.	Weight.	Preponderance.	Natural angle of sight.	Lengths.	
					Of bore, exclusive of chamber.	Of chamber.
SEA-COAST PIECES.						
Guns.						
		Lbs.	*Lbs.*	° ′	*Inches.*	*Inches.*
10-inch smooth-bore columbiad, model 1844	Cast iron	15, 400	740	1 21	99	12
8-inch smooth-bore columbiad, model 1844	....do	9, 240	635	1 23	100	11
7-inch smooth-bore 42-pounder, model 1841	....do	8, 465	600	....	110	....
6.4-inch smooth-bore 32-pounder, model 1841	....do	7, 200	695	....	107. 6	....
Howitzers.						
10-inch smooth bore, model 1841	Cast iron	9, 500	475	....	96	9. 5
8-inch smooth bore, model 1841	....do	5, 740	462	....	85. 5	7. 5
Mortars.						
13-inch smooth bore, model 1841	Cast iron	11, 500	....	....	26	13
10-inch smooth bore, model 1841	....do	5, 775	....	....	25	10
SIEGE PIECES.						
Guns.						
5.82-inch smooth-bore 24-pounder, model 1839	Cast iron	5, 790	395	1 30	108	....
5.3-inch smooth-bore 18-pounder, model 1829	....do	4, 913	305	1 30	108. 5	....
4.62-inch smooth-bore 12-pounder, model 1829	....do	3, 590	270	1 30	103. 4	....
Howitzers.						
8-inch smooth bore, model 1841	Cast iron	2, 614	420	1 00	38. 5	8
Mortars.						
10-inch smooth bore, model 1841	Cast iron	1, 852	....	....	15	5
8-inch smooth bore, model 1841	....do	930	....	....	12	4
FIELD PIECES.						
Guns.						
4.62-inch smooth-bore 12-pounder, model 1841	Brass	1, 757	108	1 00	74	....
3.67-inch smooth-bore 6-pounder, model 1841	....do	884	47	1 00	57. 5	....
Howitzers.						
5.82-inch smooth-bore 24-pounder, model 1844	Brass	1, 318	146	1 00	56. 25	4. 75
4.62-inch smooth-bore 12-pounder, model 1841	....do	788	95	1 00	46. 25	4. 25

ordnance, United States land service.

Lengths.			Distances.			Diameters.					
									Chamber.		
Nominal, without cascabel.	Total.	Trunnions.	From rear base ring to muzzle.	From axis of trunnions to face of muzzle.	Between rim-bases.	Maximum.	At swell of muzzle.	Of trunnions.	Maximum.	Minimum.	Windage.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
122. 67	126	9	120	73. 5	31	32	21. 5	10	8	....	0. 13
120. 82	124	6. 5	119	73. 5	25	26	17	8	6. 4	....	0. 13
120. 5	129	6. 5	117	70. 3	22	24. 4	16. 8	7	....	....	0. 16
117. 7	125. 7	6	114	68. 6	20. 7	23. 4	15. 4	6. 4	....	....	0. 15
115. 75	124. 25	7. 5	112	67	25	26. 5	20. 25	8	7	....	0. 13
101	109	6	98	57. 4	20. 7	22. 2	16. 5	6. 4	6. 4	....	0. 12
....	53	8. 5	....	47	36	36	35. 5	12	9. 5	7. 25	0. 13
....	46	6. 5	....	41. 5	27. 5	27. 5	27. 5	9	7. 15	5. 64	0. 13
116. 5	124	5	114	68. 09	18	21. 4	15. 586	5. 82	....	....	0. 14
116. 25	123. 25	4. 75	114	67. 85	16. 8	19. 75	13. 87	5. 3	....	....	0. 13
110	116	4. 5	108	63. 69	14. 8	17. 4	11. 864	4. 62	....	....	0. 10
54	61. 5	5	52	25. 09	18	18. 25	16. 45	5. 82	4. 62	....	0. 12
....	28	5	....	24	20. 5	20. 75	20. 75	8	7. 6	5	0. 13
....	22. 5	4	....	19. 5	16. 25	16. 5	16. 5	6	6. 08	4	0. 12
79. 2	85	3. 5	78	44. 99	12	13	10. 34	4. 62	....	....	0. 10
60. 9	65. 6	2. 8	60	34. 91	9. 5	10. 3	8. 25	3. 67	....	....	0. 09
66	71. 2	3. 25	65	35. 4	11. 5	12	9. 75	4. 2	4. 62	....	0. 14
53. 9	58. 6	2. 8	53	27. 91	9. 5	10	8. 2	3. 67	3. 67	....	0. 10

PHYSICAL PROPERTIES OF METALS.*

The qualities with which we are more particularly concerned are the physical properties of malleability, ductility, hardness or softness, toughness, elasticity, and tensile strength, while we must also understand what is meant by tenacity and elastic limit as applied to metals.

Malleability is the property of being permanently extended in all directions without rupture by pressure (as in rolling) or by impact (as in hammering). It is opposed to *brittleness*, which is the tendency to break more or less readily under compression either gradual or sudden.

Ductility is the property of permanently extending or drawing out, by traction, as in wire drawing. A metal is said to be *soft* when it yields easily to compression without breaking, and does not return to its original form on the removal of the compressing stress.

These terms are, of course, only comparative; thus we have hard leads and soft leads, while any sort of lead whatever is soft as compared with wrought iron, which latter again is called soft when we compare it with cast iron.

Steel is called *soft* or *low* when the proportion of carbon contained in it is small, and *hard* or *high* when the contrary is the case, because when treated in a similar manner one variety is much harder than the other. It should, however, be remembered that a tolerably soft steel may be made very hard by tempering.

It is easy to understand what *toughness* means, but not so easy to define exactly what it is. Dr. Young (Nat. Phil., i, 142) gives the following explanation of the term as applied to steel:

> Steel, whether perfectly hard or of the softest temper, resists flexure with equal force when the deviations from the natural state are small, but at a certain point the steel, if soft, begins to undergo an alteration of form; at another point it breaks if much hardened, but when the hardness is moderate it is capable of a much greater curvature without permanent alteration or fracture, and this quality, which is valuable for the purposes of springs [and also for gun-barrels], is called toughness, and is opposed to rigidity and brittleness on the one side and to ductility on the other.

Elasticity is the property possessed by a metal of resisting permanent deformation when subjected to a stress, and is measured by the ratio of stress to strain, so that the modulus of elasticity is equal to the co-tangent of the angle H A J (in figure).

The *elastic limit* of a metal is the tension which causes permanent elongation, and in the figure is represented by the abscissa A J.

Tenacity is the tension required to produce rupture, and is represented above by the abscissa A D.

Tensile strength we shall employ to denote the work done upon the metal to produce rupture by traction. It would be measured in the figure by the area A B D.

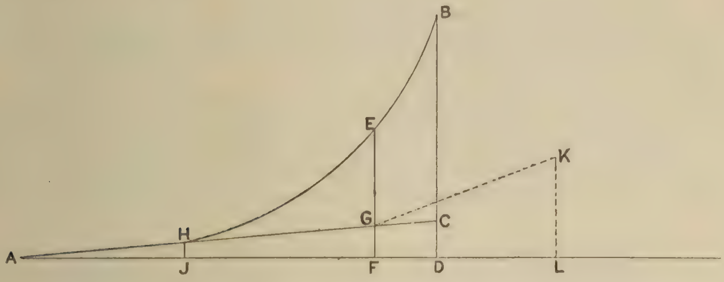
In order to understand these several terms more clearly, let us take the figure below, in which the abscissa represent the tensions, and the ordinates the extensions of a bar of metal (experimentally determined) corresponding to the tensions.

If the bar be subject to a constantly-increasing tension, the extension is at first in a constant ratio to the tension, increasing after a certain point in a varying ratio. This point, represented in the diagram by the extension H J, and measured by the tension represented by the abscissa A J, is termed the elastic limit.

* The following information on metals is taken from Captain Owen's, R. A., excellent work, "Treatise on the Construction of Ordnance."

After this point is reached, the extensions increase in a higher ratio for every increment of tension, and the line joining the ordinates becomes a curved line, as shown by H B in the figure.

As we continue to increase the tension, we arrive at a point where the bar will fracture.



Suppose the total extension of the bar at that point to be represented by B D, and the breaking tension by the abscissa A D, which is the measure of the tenacity or limit of fracture, we have then, as will be seen by the figure, three extensions of the bar, the total, elastic, and permanent, the former being in all cases the sum of the two latter; while, until the elastic limit is reached, the total extension is synonymous with the elastic extension.

The ordinates of the curve (a straight line as far as H) A B represent the total extensions, and the ordinates of the straight line A C the elastic extensions of the bar, while the work required to produce rupture is measured by the area A B D, which thus measures the tensile strength.

Similarly, the work necessary to produce a total extension, E F, is measured by the area A F E. If we move the tension represented by A F, after the bar has been extended by E F, the greatest extension of the bar will not exceed F G; then reimpose it and once more remove the tension, the bar will revert to its former length.

Here, of the total work done on the bar represented by the area A F E, that portion corresponding to the area H E G has been absorbed by it and applied to the rearrangement of its molecules, being the measure of the loss sustained in the tensile strength of the bar. Its tenacity may, however, be increased, and we see that its elastic limit is so, for any ductile metal increases (within certain limits) in elastic limit and ultimate strength (as represented by the tenacity), though not in absolute or tensile strength (as shown by the total work required to produce rupture), when subjected to drawing, hammering, or rolling. In fact, a material strained beyond its elastic limit will exhibit the same characteristics as an originally harder metal.

To return, however, to the case in the figure. Suppose we now subject the bar, which has been elongated by the permanent extension E G, to a greater tension, then the total extensions may be represented by the same line G K, and we see that the breaking tension, shown by A L, is greater than before. The total work to produce rupture will now be represented by the area A K L, which, however, can never exceed the mechanical work represented by A B D, or, which is the same thing, F G K L cannot exceed B D F E, so that the absolute or tensile strength of the metal is not increased by permanent extension beyond

its original elastic limit, although its tenacity and elasticity may be increased by the operation.

To recapitulate, then, we must remember that increase in the tenacity (or breaking tension) and limit of elasticity do not necessarily imply greater working strength in a given bar of metal.

We do, however, gain very much, as we all know, by subjecting metals to the operations of rolling, hammering, &c., for we obtain a higher limit of elasticity and tenacity in smaller bulk by making the mass more homogeneous.

It will be seen that the tensile strength of a metal is by no means the same as the tenacity, which latter is often termed tensile strength, and which is measured here by the weight in tons that a bar of a square inch in sectional area will just support without breaking. The former is proportional to an area and the latter to a straight line in the figure above.

In order to fracture steel of great tenacity, less work may in fact be done than is required to fracture a similar bar of soft wrought iron.

Again, the elasticity of the iron may equal that of the steel, but the limit of elasticity might be very different in the two cases. The elasticity is measured by the co-tangent of the angle C A D in the figure, while the elastic limit is represented by the tension measured by the line A J, and the work required to overcome it by the area H A J.

METALS USED FOR CONSTRUCTION OF ORDNANCE.

The metals employed in constructing are bronze, cast or wrought iron, and steel.

Bronze.

Bronze is a mixture or alloy of copper and tin. That particular sort of bronze formerly used for guns is often called gun metal, and consists of about 90 parts of copper and 10 of tin.

Bronze is a tough and tenacious metal, but when cast or founded in the ordinary way it is comparatively soft and is easily indented and damaged by the projectile. When heated, as, for instance, by rapid firing, this metal becomes still softer and so more readily damaged.

For the small smooth-bore guns formerly used in the field bronze answered tolerably well, as the weight of shot was comparatively small; but with rifled guns using much heavier charges, bronze is not found to be a sufficiently good material.

Besides the faults above mentioned, which are inherent to bronze cast in the ordinary way, even when the casting is sound, this alloy has the serious defect of never being quite homogeneous.

The tin has a much lower melting point than copper (442° F. as compared to 1,800° F.), while its specific gravity is also very different (and although definite alloys can be found, they are not represented by the above proportion, nor such as would answer for gun metals.)

While cooling, the two metals forming the alloy seem to separate more or less from one another, the tin liquating or sweating out in parts and causing white spots or blotches called "tin spots," which are readily acted upon by the powder gas and eaten away, leaving flaws or holes in the bore of the gun.

In rifled guns this defect is much more serious than in smooth-bore pieces, for the grooves cut in the bore lay open a further surface and expose more tin spots, while the powder gas acts with greater force (on

account of the larger charges and heavier projectiles used), and eats way the spots more quickly.

With smooth-bore bronze guns much inconvenience was occasioned by the softness of this alloy, especially when heated by rapid firing, and as experience was gained concerning rifled ordnance in the field, it was found that the defects inherent to ordinary bronze were, as mentioned above, still more serious in such pieces. Their accuracy was affected by much firing, and the greater pressure in the powder chamber quickly developed flaws by burning out the tin spots. The cutting of the grooves also laid bare many of these spots, which otherwise would not have been apparent.

Various attempts have been made to discover a modification of bronze, or some analogous alloy, sufficiently hard, elastic, and strong for the purpose required, but as yet, unless the bronze steel mentioned below be a success, all these attempts have failed.

It has also been attempted to improve its quality both in hardness and homogeneity by altering the proportions of the two constituents, and by adding small portions of other metals or non-metals, such as manganese and phosphorus.

Phosphor bronze containing small quantities of phosphorus has been extensively tried, and gives a metal of more uniform character and also stronger than bronze.

In 1872 an exhaustive trial was undertaken at Bourges by the French Government with 4-pdrs.; four of these pieces were cast, two being of ordinary bronze and two of an alloy of phosphor bronze.

The superiority of the latter over the guns cast from ordinary bronze was so slight that the committee carrying on the experiments concluded that any advantages were more than neutralized by the necessity of adding the phosphorus in very exact proportions, and so further complicating the manufacture of bronze guns.

Colonel Rosset, of the Italian Artillery, superintendent of the arsenal at Turin, has for some years past been carrying on a series of interesting trials with regard to bronze and other metals in the arsenal at Turin, where a 7.5c. gun of phosphor bronze was tested in comparison with others of ordinary bronze. This gun stood the trial well, and the alloy from which it was cast (in an iron mold) showed a tenacity of about 25 tons per square inch. Notwithstanding this, however, Colonel Rosset concluded that it was not advisable to employ such an alloy in gun manufacture on account of the unstable character of phosphorus, and the great difficulty of securing uniformity of result in the mixture of this element with bronze.

Russia, too, has been making much advance in the working of bronze, and is manufacturing some powerful experimental field-guns (Lavroff guns) of this alloy treated in the same way as described with regard to the Austrian "Uchatius" field pieces.

In Austria great attention has always been paid to bronze and analogous alloys, and General Von Uchatius, the director of the gun foundry at Vienna, has for years studied the subject. In a lecture lately delivered by him, he tells us that about three years ago his attention was particularly called to a fragment of bronze, cast under pressure, which the Archduke William had brought from Russia. He found the properties of this metal so far superior to those of bronze cast in the ordinary way that he was led to researches which resulted in his casting bronze in an iron mold, or chill casting, and at the same time chilling the interior of the mass by means of a core of solid copper, or otherwise.

This bronze, which is an ordinary alloy, containing 8 per cent. of tin,

can be forged cold, and possesses many of the properties of steel, and has, consequently, been termed "bronze steel;" it possesses, however, apparently, the advantage over steel of being a safer material when employed alone.

Iron.

Although there exists but one elementary metal which can properly be termed iron, yet when this is mixed or alloyed with comparatively small quantities of other elements, we have in these alloys or mixtures virtually distinct metals, which differ from one another in their external character more than many chemically distinct metals.

These different varieties of iron may be divided into groups termed respectively, cast iron, wrought iron, or piled metal, steel or ingot metal. Regarding the two latter we shall also see that, according to the latest nomenclature, they differ from each other more in the mode of mechanical treatment they undergo during their production than in chemical constitution.

Iron is usually obtained from its ores by melting these in large blast-furnaces with coke or coal, various fluxes being added, according to the nature of the ore, to carry off the earthy matters. The metal so obtained is run into sand molds in the shape of the well-known rough-looking bars technically termed "pigs," or "pig-iron."

The metal in this state, as run from the blast-furnace, is termed cast-iron, and contains many foreign elements, principally carbon and silicon, the former being mostly derived from the fuel with which the ore is smelted. Besides these impurities, small quantities of sulphur, phosphorus, and manganese are commonly found in cast iron when first run out.

Cast iron.

By refining, &c., a portion of the carbon and other impurities may be removed, but so long as the proportion of the carbon is not less than 2 per cent. the metal will possess the characteristic properties of cast iron mentioned below. The presence of silicon, sulphur, and phosphorus modifies the strength, brittleness, &c., of cast iron very much, that of sulphur in particular increasing its tenacity, which is always, however, comparatively low.

We may say that cast iron contains from 2 per cent. to 5 per cent. by weight of carbon, which exists in two states, either chemically combined with the iron or mechanically mixed with it.

In the trade, cast iron is distinguished by numbers from one to eight, the lower numbers being given to those descriptions in which the surface when broken presents a gray or mottled appearance, and in which the larger part of the carbon is in the state of graphite—that is, uncombined with the iron. The higher numbers represent white or bright iron, and in these the carbon is almost entirely in the combined state.

Cast iron is easily fused, and can be readily cast into a homogeneous mass of any size or shape we choose, but it is brittle and cannot be worked under the hammer either hot or cold. If, indeed, we heat a mass of cast iron to a red heat and hammer it, it will crumble to pieces, a fact taken advantage of in the breaking up of obsolete smooth-bore cast-iron guns.

Wrought iron.

If we remove the carbon still further from cast iron, so that the amount becomes less than 2 per cent., we obtain either *steel* or wrought iron according to the amount removed, the subsequent treatment of the metal, or to both combined.

Wrought iron approaches to, theoretically, pure iron, and, according to the old nomenclature, is iron containing from 0.1 per cent. to 0.3 per cent. of carbon, though we shall find that certain characteristic steels now made have no larger proportion of this element.

Wrought iron is obtained by removing the carbon from cast iron by puddling or otherwise, and then working it up by hammering or rolling into a useful or marketable form, whence the term wrought or piled is applied to this particular kind of iron.

If the cast iron is very impure, some of the impurities will be retained by the wrought iron, and will affect it seriously if present in any quantity. Thus a small proportion of phosphorus, 0.25 per cent., will make a bar of wrought iron "cold short" or brittle when cold, while a little sulphur present makes wrought iron "red short" or brittle when heated.

While this more or less pure metal obtained from cast iron by removal of the carbon, through puddling or otherwise, is worked under the hammer or rolls, it is drawn out and so given a fibrous structure, the fibers running lengthwise in the direction in which it is drawn. The fiber runs along the length, in fact, as the fiber runs in the branch of a tree.

This structural arrangement of the material can be readily demonstrated by subjecting a piece cut off a bar of wrought iron to the action of acid, when certain portions of the mass are eaten away, and the fibers stand out clearly, presenting the appearance of a bundle of fine wires. This fibrous quality of bar iron renders it much stronger in one direction than in the other, for—just as in the case of wood—it requires about twice the force to break a piece of wrought iron across its fiber that it does to tear it asunder along the fiber. In the latter case the fibers need only be separated, not broken, and the cohesion which binds them together is not much greater than that of the crystals which compose good cast iron.

Unfortunately the process of working up wrought iron into a proper condition for use does not remove all the foreign matter, such as minute portions of slag, &c., which have been entangled amongst the particles and fibers, so that owing to its mode of treatment a mass of wrought iron is never thoroughly homogeneous, and if laid open always exhibits flaws of some description, whence it is difficult to obtain a uniform and smooth surface of wrought iron perfectly free from defects.

Wrought iron may be said to be practically infusible in any ordinary furnace, but it has the property of welding (which cast iron has not); that is, if two clean surfaces of wrought iron heated to a white heat (about 3,000°) be brought into contact and pressed together, either by rolling or hammering, they will unite so perfectly that the mass when broken will part as readily at any other place as at the point of union; this is a most valuable property, and is largely taken advantage of in the construction of our service ordnance.

Wrought iron is very malleable and ductile, and is also of great tensile strength, although its tenacity is much below that of most natures of steel. The tenacity is about 25 tons per square inch for good average wrought iron.

The elastic limit of wrought iron is not very high, about 12 tons per square inch; but after that limit is exceeded much work must be done in permanently stretching this very ductile metal before the limit of fracture is reached, giving us a large margin of safety.

Steel.

To give a short definition of steel is a difficult task. Until lately, steel has been usually defined to be iron containing a small amount of carbon,

an amount less than that present in cast iron, but greater than the maximum quantity to be found in characteristic wrought iron; *i. e.*, iron containing between 0.3 per cent. and 2 per cent. of carbon was termed steel. This proportion of carbon is, however, only approximate, and Dr. Percy gives from 0.5 to 0.65 per cent. of carbon as the limit at which, when free from other foreign matter, iron may be considered as passing into steel, so that when hardened by quenching in water it will strike fire readily with flint. According to this definition, where carbon is present "in certain proportions, the limits of which cannot be exactly prescribed, we have the various kinds of steel, which are highly elastic, malleable, ductile, forgeable, weldable, capable of receiving very different degrees of hardness by tempering, and fusible in furnaces."

Owing, however, to the gradual development of new modes of manufacture, and to the enormous increase in recent years in the production of cast steels of all kinds, the arbitrary definition of steel above given leads to much confusion and serious mistakes, and though it may be called a mere question of words, the above definition has no doubt exercised a deleterious effect upon the introduction of steel in place of worked or wrought iron for many purposes for which it is well suited.

A simpler definition of steel seems likely to be adopted, a definition which possesses the advantages of precision and is in harmony with the current modes of manufacture. According to this, *steel is an alloy of iron cast while in a fluid state into a malleable ingot.*

It is held, according to this nomenclature, that steel and wrought iron cannot always be distinguished by chemical analysis (for the same proportions of carbon, manganese, silicon, &c., may exist in any malleable alloy of iron), and that the fundamental and essential difference between steel and compounds of iron, merely worked or wrought, is a structural difference easily determined.

All malleable products of iron industry—that is to say, all varieties of iron, except cast iron—may be divided into piled metal (wrought iron) and ingot metal (steel); the former embracing all malleable iron or alloys of iron produced without fusion of the metals while in a malleable state, and the latter applying to all irons, however produced, which are cast into a malleable ingot.

"These two classes differ more widely in mode of manufacture, appearance, and in many important properties than the varieties of each class among themselves, and form two parallel and continuous series, the corresponding members of which are chemically identical, differing only in mode of production and in mechanical structure, and rising in each series from the purest and softest iron to the hardest and most highly carbureted varieties."

M. Adolph Grenier, of Seraing, adopting this definition of steel, classifies the two parallel series of products, the irons and the steels, as follows:

Percentage of carbon.

0. to 0.15	0.15 to 0.45	0.45 to 0.55	0.55 to 1.50 or more.

Series of the irons.

Ordinary irons.	Granular irons.	Steel irons or puddled steel.	Cemented steel, Styrian steel.

Series of the steels.

Extra soft steels.	Soft steels.	Half soft steels.	Hard steels.

The production of the more highly carbureted varieties of the iron group, such as puddled steel or cement steel, except with the view to casting the metal subsequently, is now carried on upon a comparatively limited scale, while that of the steels proper, or cast steel, is increasing enormously each year.

For the construction of ordnance, we may say that cast steel is at present and will in the future be as a rule employed, so we may safely take the new definition of steel and look upon this metal *as a melted malleable alloy of iron produced in any way whatever, and containing a smaller proportion of carbon or other hardening element than is contained in cast iron.*

Steel may be produced in a variety of ways, by more or less decarbureting cast iron under such conditions as to obtain a melted product.

By dissolving wrought iron or steel scrap, or spongy reduced iron in melted cast iron.

By the direct melting of puddled iron, or other variety of iron of the requisite degree of hardness (the hardness referring to the amount of carbon in the iron).

By melting a mixture of soft wrought iron, or iron sponge, with carbon or with cast iron or of malleable iron, which is too hard for the variety of steel required, with oxidizing agents, or by directly melting together a mixture of iron ore and carbon as a single operation.

The processes by which steel-making is practically carried out are by melting in pots or crucibles, giving "pot" or "crucible" steel; on the open hearth or bed of a reverberatory furnace, giving Siemens or Siemens-Martin steel; or by blowing air through molten cast iron, producing Bessemer steel. In whatever way made, the material is essentially the same, depending on its chemical composition and physical structure for its properties. It differs much from wrought iron, even when chemically the same metal, because a mass of wrought iron is made up from a number of bars or blooms heated and welded together, each of these again being composed of separate granules with impurities interposed, such as slag, &c., entangled so that the mass is unavoidably full of flaws and imperfect welds. Steel, on the other hand, has been brought into a state of perfect fusion, and cast while liquid into a malleable ingot, which is homogeneous throughout and free from flaws or intermixed impurities.

We now can understand fully what steel means in accordance with either of the definitions given of the term, whether depending merely upon its chemical constitution as to the amount of carbon present or upon the physical treatment of the metal, which must be melted and cast into a malleable mass.

In either case it is evident that the properties of the metal must vary very much, but more especially if we adopt the second definition. The soft or low steels approximate, like ordinary wrought iron, to pure iron, and the hard or high natures of steel approach cast iron in their properties.

Over wrought iron steel has always the advantage of being homogeneous, but it is unfortunately uncertain in quality, a surprising fact when we think how it is produced; still it is so, and we find that ingots of this metal of the same chemical constitution, produced in the same way and from identical materials, often differ much from one another in the properties of elasticity and tenacity.

Many nostrums have been proposed for overcoming this defect, which appears to be due to the molecular condition of the metal as affected during the melting and the subsequent treatment of the ingot.

It is in modification and improvements of the la t appears to lie, and already many plans are being attempted for the insurance of greater certainty in the quality of steel, such, *e. g.*, as casting it under pressure to get rid of the bubbles or blow-holes.

Steel will not, like wrought iron, stand a high welding heat, especially if it be of a "hard" or "high" nature. If hammered at too great a heat the ingot will fall to pieces.

After being cast, steel is hammered or rolled, and it acquires a fibrous structure during this process, as may be easily shown if a bar of this metal be acted on by a strong acid.

When first cast, steel, excepting the higher varieties, is comparatively soft and inelastic, and can thus be treated in a similar manner to wrought iron; but, with the exception of the very low or soft varieties, it may be subsequently hardened by what is called "tempering," when the metal is heated and plunged into mercury, water, oil, or some other liquid, in order to cool it more or less quickly. The effect of such tempering depends very much upon the amount of carbon present in the steel, as well as upon the degree of heat it is previously raised to, and has a marvellous effect in increasing both tenacity and elastic limit in the case of good steel.

Besides the great uncertainty of steel, we must remember that it is very inferior to wrought iron in another important point, that of being easily weldable. The importance of this property with regard to facility and economy in working large masses of metal can hardly be exaggerated.

To sum up the qualities of steel:

In tenacity it varies, roughly speaking, from 30 to 60 tons per square inch, and its limit of elasticity lies between 13 and 30 tons.

The softer the steel the more ductile it is, the less readily can it be tempered, the lower in its limit of elasticity and tenacity. Other things being equal, the more rapidly it is cooled the harder it becomes; but at the same time the higher natures are rendered more brittle. When cooled in a comparatively bad conductor of heat, such as oil, the mass parts with its heat slowly, and is not only made more elastic and harder, but also toughened; while in any case the limits of elasticity and tenacity approach one another more nearly.

The effect of tempering upon the metal is, of course, comparative; thus experiments have shown that certain soft steels containing from 0.15 per cent. to 0.22 per cent., or 0.24 per cent. of carbon, were decidedly toughened by heating to a red heat, and then being quenched in water. The steel used for Woolwich gun-barrels, containing about 0.3 per cent. of carbon, would be made very hard, but also very brittle, if so heated; therefore it is tempered in oil, as being a worse conductor of heat than water, and is thus toughened.

This is shown well by the following table given by Mr. Kerkaldy:

Nature of specimen.	Tenacity (tons per square inch).	Elongation, per inch.	Character of fracture.
1. Highly heated and cooled in water	30	0	Entirely granular.
2. Highly heated and cooled slowly	36½	22	Entirely fibrous.
3. Moderately heated and cooled in oil	53	14½	One-third granular, two-thirds fibrous.
4. Highly heated and cooled in oil	58	2½	Almost entirely granular.

Should the steel be too highly carbureted, or be in too large a mass, it is liable to fracture during the process of toughening.

With the higher natures we can obtain very great strength and elasticity, though we lose in ductility, and have a more brittle material.

We have also the great advantage of hardness and homogeneity, giving us, when required, a very smooth surface quite free from flaws.

Until further improvements are made, the advantages are counterbalanced by great uncertainty as to the behavior of the material, especially in the higher or harder steels. The greater cost of steel of sufficiently good quality is also a disadvantage when we compare it with wrought iron.

The brittleness and uncertainty of this material prevent us employing steel as a sole material for any gun save the small 7-pounder for boat and mountain service. Although, however, steel is not such a material as we as we should employ for the sole manufacture of a gun, yet it is admirably suited for the inner barrel, as it is very strong and gives a hard, clean surface, while its limit of elasticity is high, so that even a heavy strain does not stretch it permanently and deform the bore. It may indeed split if subject to too great a pressure when not properly supported by the exterior layers, but by putting a wrought-iron jacket outside we prevent any danger from that cause; for, should the steel tube burst, the wrought-iron exterior will prevent any explosive rupture.

AMERICAN METALS FOR CANNON.

Mean mechanical properties of American cast iron, employed in rifle guns of large caliber, as determined by the tests of a trial cylinder, 60 inches long with an elliptical base 24 inches by 19.5 inches.

Original dimensions of specimens.	Nature of property.	
	Density	7.2771
Area, 1,001 square inches	Tenacity per square inch	33,875
	Hardness	18.46
	Hardness of copper	3.33
Length, 30″; diameter, 1″.385; area, 1″.5065.	Pulling stress per square inch:	
	Elastic limit ... pounds	9,750
	Ultimate resistance ... do	31,000
	Ratio of elastic to ultimate resistance ... per cent	31.45
	Extension per inch at elastic limit ... inch	0.00051
	Ultimate extension per inch ... do	0.00337
	Ultimate restoration per inch ... do	0.00199
	Ultimate set per inch ... do	0.00163
	Reduction in area at point of rupture ... per cent	0.215
	Ultimate resistance per square inch fractured area, pounds	31,065
	Appearance of fracture: bright gray medium sized crystals.	
Length, 10″; diameter, 1″.385; area, 1.″5065.	Thrusting stress per square inch:	
	Elastic limit ... pounds	8,200
	Compression per inch at elastic limit ... inch	0.00093
	Compression per inch under 43,000 pounds ... do	0.00619
	Restoration per inch under 43,000 pounds ... do	0.00344
	Set per inch under 43,000 pounds ... inch	0.00275
	Increase in area of cross-section after 43,000 pounds, per cent	0.371
Length, 2″; diameter, 0.″8	Absolute resistance to crushing force ... pounds	114,143
	Bending stress:	
Length, 20″; breadth, 1″.075; depth, 1″.075	Transverse resistance ... do	11,556
	Bursting stress:	
Cylinder: length, 5″; exterior diameter, 3″; interior diameter, 1″	Ultimate resistance ... do	63,184

Mechanical properties of steel manufactured at Midvale Works, Nicetown, Pa.

Original dimensions of specimens.	Nature of property.	
	Density	7.8483
	Tenacity	113,220
	Hardness	18.00
	Hardness of copper	3.33
	Pulling stress:	
Length, 10″; diameter, 0″.65	Elastic limit ... pounds	50,000
	Extension per inch at elastic limit ... inch	0.0023
	Ultimate resistance ... pounds	90,000
	Ultimate extension per inch ... inch	0.1898
	Ultimate restoration per inch ... do	0.0052
	Ultimate permanent set per inch ... do	0.1358
	Thrusting stress:	
Length, 10″; diameter, 1″.165	Elastic limit ... pounds	25,000
	Compression per inch at elastic limit ... inch	0.00097
	Compression per inch under 45,000 pounds per square inch ... inch	0.0092
	Corresponding restoration per inch ... do	0.00159
	Corresponding permanent set per inch ... do	0.00033
	Bending stress:	
Length, 20″; diameter, 2″ × 2″	Elastic limit ... pounds	5,000
	Deflection at elastic limit ... inch	0.03
	Deflection under 25,000 pounds ... do	0.645
	Corresponding restoration ... do	0.151
	Corresponding permanent set ... do	0.498
Length, 2″; diameter, 0″.8	Resistance to crushing force ... pounds	135,000

Mean mechanical properties of American bar iron employed in the fabrication of coiled wrought-iron gun-tubes.

Original dimensions of specimens.	Nature of property.	
	Density	7.6750
Area, 0″.3334	Tenacity per square inch, pounds, Along the fiber	52,500
	Tenacity per square inch, pounds, Across the fiber in the direction of the piling	39,790
	Tenacity per square inch, pounds, Across the fiber and across the piling	25,400
	Hardness	7.60
	Hardness of copper	3.33
	Pulling stress per square inch:	
Length, 2″; diameter, 0″.650; area, square inch, 0″.3318	Elastic limit ... pounds	22,500
	Ultimate resistance ... do	52,000
	Ratio of elastic to ultimate resistance ... per cent	43.27
	Extension per inch at elastic limit ... inch	0.0025
	Ultimate extension per inch ... do	0.3100
	Reduction in area at point of fracture ... per cent	47.95
	Ultimate resistance per square inch of fractured area, pounds	99.9210
	Appearance of fracture	Smoky gray, fibrous.

* *Chemical analysis of cast iron employed in casing of 12.25-inch rifle.*

	Muzzle.	Breech.
Silicon	1.150	1.094
Phosphorus	.362	.355
Manganese	.933	.877
Copper	.008	.012
Cobalt	.042	.049
Nickle	.020	.034
Chromium	.016	.020
Aluminum	.017	.011
Sulphur	.032	.025
Combined carbon	1.440	.079
Graphite	2.018	2.955
Oxygen	0.178	0.069
Iron, direct	94.192	94.647
	100.408	100.227

* Determined by Capt. J. Pitman, Or dnance Department, U. S. A.

**Chemical analysis of American tube iron.*

	Muzzle.	Breech.		Muzzle.	Breech.
Silicon	.121	.158	Sulphur	.007	.003
Phosphorus	.184	.202	Graphite	.005	.016
Manganese	.022	.019	Combined carbon	.037	
Cobalt	.044	.049	Oxygen	.601	....
Nickel	.013	.021	Iron	†99.057	99.500
Copper	.014	.010			
Chromium	None.	None.		100.161	99.978
Aluminum	.056	....			

* Determined by Capt. J. Pitman, Ordnance Department, U. S. A.
† Slag and oxide of iron, 2.178.

Mechanical properties of United States bronze.

Nature.		Composition.	Density.	Tenacity per sq. inch.	Limit of elasticity per square inch.	Elongation. Ultimate.	Elongation. Elastic.	Hardness.
				Lbs.	*Lbs.*	*Pr. ct.*	*Pr. ct.*	
U. S. Navy guns	Breech square	90 parts copper.	8.765	46,500	....	......	......	......
	Gun-head	10 parts tin	8.444	27,400	....	......	......	......
Do		....	....	60,000	....	......	......	......
U. S. Army field guns	Gun-head samples	....	8.497	29,859	....	......	......	......
	Small bars	90 parts copper.	8.557	42,754	....	......	......	*4.57
	Finished gun	10 parts tin	8.766	....	....	......	......	5.94
	Small bars	....	8.800	52,000	....	......	......	......
Reed brass (South Boston Iron Company)		Copper, zinc	8.4142	55,800	9,000	24	100	6.27
West Point foundry bronze, for life-saving mortars		90 parts copper.	8.7972	50,831	17,000	56	200	4.57
		10 parts tin	....	....	20,000	42	200	5.24
South Boston Iron Company bronze, condensed by mandreling		Uncondensed	8.3512	35,810	....	......	......	5.40
		Condensed	8.7065	51,571	....	......	......	†18.00

* Hardness of copper, 3.33. † Hardness of cast-iron, 18.46.

Initial tension, tenacity, &c., of cast-iron guns in service.

Guns.	Where taken.	Density.	Tenacity.	Initial tension.	Ratio of initial tension to tenacity.
					Per ct.
8-inch Rodman S. B. muzzle ring	....	7.1856 to 7.3400	25,599 to 34,671	......	......
10-inch Rodman S. B. muzzle ring	....	7.1590 to 7.4298	25,471 to 38,886	3,000 to 28,000	12 to 72
13-inch Rodman S. B. muzzle ring	....	....	....	....	....
15-inch Rodman S. B. muzzle ring	....	7.1855 to 7.3820	27,150 to 40,699	4,000 to 25,000	15 to 61
20-inch Rodman S. B. muzzle ring	....	7.3028	28,737	......	......
10-inch Rodman rifle	Outside	7.3042	35,066	1,800	52
	Middle	7.3024	33,088		
	....do	7.2829	34,346		
12-inch Rodman rifle	Outside	7.3126	32,187	......	......
	Middle	7.2929	31,579		
	Inside	7.3145	34,059		
12-inch wrought iron lined rifle, muzzle ring	Outside	7.3414	40,347	19,500	54
	Middle	7.2707	33,673		
	Inside	7.2943	35,352		
	Radial spec.	7.2728	33,881		
Ring from 12.25-inch experimental (Thompson) rifle casing, muzzle ring	Outside	7.2729	34,529	18,500	56
	Middle	7.2836	30,711		
	Inside	7.2900	33,866		
Ring from 9-inch experimental (Sutcliffe) rifle casing, muzzle ring	Outside	7.3277	36,742	16,500	48
	Middle	7.3039	31,443		
	Inside	7.2998	33,216		

CAST-IRON GUNS.*

STANDARD OF IRON.

Smelting of iron for cannon.—It is in the smelting furnace that the character of the iron is fixed. Iron of good character and high susceptibility may be spoiled by treatment at the foundry; but this, with ordinary experience and intelligence, ought but rarely to occur. But from iron that leaves the smelting furnace with bad qualities it is impracticable, with our present knowledge, to make good and reliable guns.

The smelting of iron is a purely chemical process, and should be conducted with the same regularity and precision as any other important chemical process. Though, with every precaution, perfect uniformity in the quality of the iron produced from day to day cannot be expected, in consequence of the many disturbing causes which tend to affect its character, yet a near approximation to it is practicable.

All the stock for a "blast" of gun iron should be carefully prepared and housed before beginning to "blow." The ore should all be roasted and well mixed so as to be as nearly uniform, as to size of lumps and all other qualities, as possible. The charcoal should all be made as nearly as possible from the same kind of wood, and well mixed together after charring. All the stock should be carefully weighed and supplied to the furnace at regular intervals of time.

The pressure, temperature, and hygrometrical condition of the "blast" should be kept as nearly constant as possible. The temperature of the blast may be kept very nearly constant without using what is termed a "hot blast," by warming it just enough to bring it above the highest summer temperature.

The quantity of moisture may, it is believed, be kept nearly constant by passing the blast some distance over water heated to the proper temperature. And this may be readily done by passing the blast through a long horizontal tube, like a cylindrical steam boiler, partly filled with water, and kept at a constant temperature by the waste heat from the furnace. The temperature of the water should be such as to saturate the blast with moisture, and thus render it hygrometrically independent of atmospheric changes.

Piling the pigs.—Supposing a standard of quality to have been determined, with the stock all prepared for a given number of guns, and having determined by comparison with the *standard* the quality of iron required, a further approximation to identity in quality of the metal in the guns may be made by casting each run of metal from the smelting furnace into a number of pigs of equal size, something greater than the number of guns to be made, and piling them in separate piles—each run of metal furnishing one pig to each pile. Each pile should contain iron enough for one gun and one test cylinder, and be kept separate and distinct from all others in transportation, and be repiled in the foundry-yard in the same order as at the smelting furnace; one gun being made from each pile, after the treatment which the iron should receive at the foundry shall have been determined by experiments made on the iron in the surplus piles. The pigs should be cast in molds prepared from a pattern, so as to be as smooth and free from adhering sand as possible.

Difference in quality.—The quality of the iron is much modified, and ordinarily improved, by remelting and long continuance in fusion. But all kinds of iron are not affected in like manner by the process. The difference between the iron as it exists when presented for use, and as

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* *References:* Rodman, Wade, Mallet, Benton, Holley.

it exists in the body of the finished gun, is very great, and has been found to be, in certain cases, more than twenty pounds per cubic foot in density, and in tenacity as 1 to 2.8. This shows how unreliable the tests of the pig iron are, as means for determining the quality of iron and its suitableness for making cannon. It is found that, though some kinds of iron are susceptible of very great improvement by different methods of treatment at the foundries, other kinds are at their maximum strength in the crude pigs. The cause of this difference in the susceptibility for change and improvement will doubtless be found in the qualities of ores used, and in the process of melting them.

In examining the effects of the different treatment of iron at the foundry, such samples should be chosen as will best exhibit the following particulars and characteristics, viz:

1st. The properties which distinguish the different grades of iron made from the same ores at the same furnace.

2d. The changes in the mechanical properties of iron produced by repeated meltings of one of these grades, separately, showing the changes effected at each melting.

3d. The changes produced by repeated meltings of the different grades of iron mixed.

4th. The changes produced in iron of the same melting and quality by casting it into masses of different bulk, and by different methods of cooling.

The softest kinds of iron will endure a greater number of meltings with advantage than the higher grades. It appears from experiments with Greenwood iron, that when it is in its best condition for casting into proof bars of small bulk, it is then in a state which requires an additional fusion to bring it up to its best condition for casting into the massive bulk of cannon.

In selecting and preparing for cannon, we may proceed by repeated fusion, or by varying the proportions of the different grades and different fusions until the maximum tenacity is attained.

Variation of density and tenacity.—An increase of density is a consequence which invariably follows the rapid cooling of cast iron, and, as a general rule, the tenacity is increased by the same means. The density and tenacity usually vary in the same order. It appears that the tenacity generally increases quite uniformly with the density, until the latter ascends to some given point; after which an increased density is accompanied by a diminished tenacity.

The turning point of density at which the best qualities of gun-iron attain their maximum tenacity, appears to be about 7.30. At this point of density, or near it, whether in proof-bars or gun-heads, the tenacity is greatest.

As the density of iron is increased its liquidity when melted is diminished. This causes it to congeal quickly, and to form cavities in the interior of the castings.

If in preparing iron for guns it is carried *too high*, either by long continuance in fusion or by using a large portion of a hard grade of iron, the casting will be lost.

High iron.—The condition of the iron at casting is said to be *too high* when the process of decarbonization has been carried too far.

Various qualities of cannon metals.

Metals.		Density.	Tenacity.	Transverse strength.	Compressive strength.	Hardness.
Cast iron	least	6.900	9,000	5,000	84,529	4.57
	greatest	7.400	45,970	11,500	174,120	33.51
Wrought iron	least	7.704	38,027	6,500	40,000	10.45
	greatest	7.858	74,592		127,720	13.14
Bronze	least	7.978	17,698			4.57
	greatest	8.953	56,786			5.94
Cast steel	least	7.729			198,944	
	greatest	7.862	128,000	23,000	391,985	

A prominent feature of this table is that which shows the great difference between the lower and higher grades of the same metal. In cast iron, the density differs as 6.9 to 7.4, a difference equal to 31 pounds per cubic foot; in tenacity it differs as 45,970 to 9,000 pounds per square inch, or as five to 1; and in hardness as 7 to 1. The bronze varies in tenacity from 56,786 to 17,698, more than 3 to 1; and in density it is as 8.953 to 7.978, equal to 61 pounds in the cubic foot.

Comparison with standard.—While the cannon are making, the inspecting officer examines and tests the metal before it is used, witnesses its melting and casting, and tests the metal in the first gun made before the second one is cast. If the first proves unsatisfactory, such changes are made, either in the material or in the treatment, as will tend to produce the desired result. This practice of ascertaining the quality of the material used, and of the casting made from day to day, as the work proceeds, enables the founder to distinguish the material, to select those of the best quality, and to treat them in the best manner. If these tests are satisfactory, the inspecting officer is assured of the good quality of the guns before any proof by firing is made. And this supersedes the necessity of using excessive proof-charges in the final proof, which may do serious and fatal injury to guns without bursting them or leaving any visible marks of injury.

Means of comparison.—The testing instrument furnishes to the founders a convenient and accurate method of comparing the qualities of iron. It therefore enables him to select his materials before casting with greater certainty and safety. He can also by these means determine the comparative utility of different methods of melting and casting the gun. As the quality of the iron is essentially changed by the different ways of treating it while in the melted state, and by the different means adopted for cooling it after it is cast into the mold, the testing instrument enables one to ascertain the effect produced by these processes in all their several stages of progress, and to decide upon that which is found most suitable for making the guns of the best quality.

Contract with founders.—The metal of guns made for service is subjected to tests to ascertain its hardness, specific gravity, and tensile strength.

The particular hardness, density, and strength which the metal must possess, is specified in the special contracts with the founder.

Each foundry keeps an accurate record of the character, mixture, and mode of working the metal of each gun, so that its foundry number will at once refer to its class, date, weight, &c.

Samples.—The quality of the iron as it exists in the gun is more accurately represented by samples taken from its sinking-head than by any

which can be obtained from other parts of the casting without injury to the gun. These samples are taken from the lower end of the sinking-head next the muzzle of the gun, and are cut out so that their axis will be parallel to the axis of the casting, at a distance from the center of the head equal to the distance between the axis of the bore and the middle of the metal in the wall of the piece when bored.

When guns burst from extreme proof, samples are taken from different parts to test the strength of the metal. The radial specimens are generally found to be somewhat stronger than the longitudinal from the same cross-section of the gun.

Crystallization.—Of the various circumstances which affect the strength of cannon metal, the most important appear to be those which connect themselves with crytallization.

General law.—It is a law of the molecular aggregation of crystalline solids, that when their particles consolidate under the influence of heat in motion, their crystals arrange and group themselves with their principal axes in lines perpendicular to the cooling or heating surfaces of the solid; that is, in the lines of direction of the heat-wave in motion, which is the direction of least pressure within the mass; and this is true, whether in the case of heat passing from a previously fused solid in the act of cooling and crystallizing on consolidation, or of a solid not having a crystalline structure, but capable of assuming one upon its temperature being sufficiently raised, by heat applied to its external surfaces, and so passing into it.

Molecular constitution of cannon metals.—The metals used in gun-construction are crystallizing bodies, which in consolidating obey, more or less perfectly, according to their conditions, this law; so that in castings of these metals, the planes of crystallization group themselves perpendicularly to the surfaces of external contour; that is, in the directions in which the heat of the fluid metal has passed outwards from the body in cooling and solidifying. Because the crystals of these metals are always small and are never very well pronounced, these directions are seldom very apparent to the eye, but they are not the less real.

Development of crystals.—Their development depends upon—

First. The character of the metal itself; all irons that present a coarse, large-grained, dark, or spangled fracture, contain a large proportion of uncombined carbon or graphite, and form in castings of equal size the largest crystals.

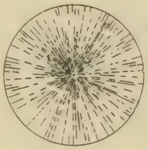
Second. The size or mass of the castings, the largest castings presenting for any given variety of metal the largest and coarsest aggregation of crystals; but by no means the best arrangement of them which depends chiefly upon—

Third. The rate at which the mass of the casting has cooled, and the regularity with which heat has been carried off by conduction from its surfaces to that of the mold adjacent to them.

Chilled castings.—Those castings in which the fluid iron is poured into a nearly cold and very thick mold of cast iron, whose high conducting power rapidly carries off the heat, presents the most complete and perfect development of the crystalline structure perpendicular to the chilled surfaces of the casting. In such, crystals are often found penetrating more than an inch into the substance of the metal, clear and well defined.

Illustrations.—These prevailing directions of crystalline arrangement may be made more clear to the eye by the accompanying figure, which shows sections of a round and a square bar of cast iron where the crystallization is well developed. In the round bar the crystals all radiate from the center; in the square bar they are arranged perpendicularly

to the four sides, and hence have four lines in the diagonals of the square in which the terminal planes of the crystals abut or interlock, and about which the crystallization is always confused and irregular. The result of this arrangement is to create *planes of weakness* where the different systems of crystals intersect.



Effect of crystallization on strength.—The size and arrangement of the crystals of a metal have an important influence on its strength. This arises from the fact that the adhesion of the crystals by the contact of their faces is less than the cohesion of the particles of the crystals themselves, and that consequently rupture takes place along the larger or principal crystalline faces. A metal will therefore be strongest where its crystals are small.

Size of crystals.—The size of the crystals of a particular metal depends on the rate of cooling of the heated mass; the most rapid cooling giving the smallest crystals. The size of the crystals or coarseness of grain in castings of iron depends for any given *make* of iron and given mass of castings upon—

First. The high temperature of the fluid iron above that just necessary to its fusion, which influences—

Second. The time that the molten mass takes to cool down and assume again the solid state.

The lower the temperature at which the fluid iron is poured into the mold, and the more rapidly the mass can be cooled down to solidification the closer will be the grain of the metal, the smaller its crystals, the fewer and least injurious the planes of weakness, and the greater the specific gravity of the castings.

Slow cooling develops a coarse, uneven grain, with large but thoroughly irregular and confused crystallization; cast iron with such a grain is never strong or cohesive, though soft and extensible.

The more rapidly a casting once consolidated can be cooled, without introducing injurious effects, the finer, closer, and more even will be its grain on fracture, and with any given metal the greater will be its strength. The rate of cooling cannot be accelerated beyond a moderate limit. If this limit be exceeded, as by casting in a cold, thick, highly conducting metallic mold, the iron is "chilled," its constitution changed, and the carbon, not having time to crystallize out, remains combined or diffused through the mass. It should not be so fast as to cause unequal contraction, nor must it be so fast in large castings, such as guns requiring to be "fed" from a *feeding* or *sinking head*, with fresh portions of hot fluid metal during consolidation to fill up the internal cavities or porosity due to contraction and crystallization, that this filling cannot be accomplished.

The larger the mass of the casting, with any given quality of iron, generally the coarser is the grain, that is, the larger are the crystals that develop themselves in the mass.

The same metal that shall produce a fracture bright gray, mottled, and without a crystal visible, in a small bar, will in a large casting produce a dark confusedly crystalline surface of fracture as coarse as granite rock.

Contraction of castings.—A certain amount of contraction, on becom-

ing solid from the liquid state, occurs in all castings. For iron this is variable and depends upon the mass of the castings, being greatest for small and least for large castings, of the same make of iron, and poured at the same temperature. There are two conditions that principally affect the degree of contraction, namely, the extent to which the fluid metal as entering the mold has been expanded by elevation of temperature, and the state of final aggregation of the particles, depending upon the size of the mass.

Effect of sudden change or form in castings.—Sudden changes of form or of dimensions in the parts of cast guns, besides the injury they do to the crystalline structure of the mass, introduce violent strains, due to the unequal contraction of the adjoining parts whose final contraction has been different.

Time required for cooling castings.—The enormous time required by a large casting for cooling is not generally known. A solid casting sufficiently large for a 15-inch gun weighs about 35 tons; it is red hot three days after having been cast, and only becomes cold enough to handle after a fortnight.

The cooling of a casting must be uniform so far as uniformity is possible. This is impossible strictly in any casting; the approach to it is most difficult in heavy solid castings, and hence the great advantage of the practice of hollow casting upon a suitably made core admitting of internal cooling by artificial means.

Effects of irregular cooling of castings.—The contraction of cast iron in becoming solid introduces strains into the mass by consolidation of one portion of the casting before another. When a large gun is cast solid and the metal cools in the ordinary way, the external portions solidify long before the interior has ceased to be liquid, and the process of solidification is propagated, as it were, in parallel layers from the outside to the center of the mass. When the first layer or thickness of solid crust has formed on the exterior it forms a complete arch all round, so that the contraction between fluidity and solidification of each subsequent layer is accommodated by portions of matter withdrawn radially from the interior towards the still cooling exterior, that is to say, from a smaller towards a larger circumference. The final effect of this propagated to the center of the mass is twofold:

First. To produce a violent state of internal tension in the particles of the metal in radial lines from the axis of the gun inward as a cylinder, tending to tear away the external portions of the mass from the internal nucleus.

Second. To produce about the center or along the axis, a line of weakness, and one in which the texture of the metal is soft, porous, and of extremely low specific gravity.

The effect of this unequal contraction may be so great as to crack the interior metal of cast-iron cannon, even before it has been subjected to the force of gunpowder, and large masses of iron which have been cooled very rapidly by casting them in iron molds have been known to split open longitudinally from no other cause than the enormous strains to which they are subjected.

Sinking-head.—Guns have long been cast in a vertical position and with a certain amount of head of metal above the topmost part of the gun itself. From this head the casting is fed with fresh portions of fluid metal during consolidation; it also affords a gathering place for all scoria or other foreign matter. But the great value of increased head of metal is in adding to the density of castings and so also to their strength. Fineness of grain, smallness of crystal, density, increased

cohesion, and elasticity are all induced by casting under largely increased statical heads of fluid metal.

Practical treatment in fusion.—In the practical treatment of iron in fusion while preparing it for casting into cannon, it may be safely continued in fusion, with increasing improvement of its quality, so long as sufficient liquidity is retained to insure an exemption from cavities in the interior of the casting. The point at which such cavities of a fatal character will form, will be reached before arriving at the point of density for maximum tenacity.

Tests while in fusion.—A convenient method for determining the condition of the iron while in fusion, and whether it has arrived at the proper condition before casting, or should be longer continued in fusion, is found in dipping from the melted pool of iron and casting into small bars, about 10 inches long, and from 1 to 2 inches square at one end and tapering to a point at the other end. The first one is taken from the furnace, and cast soon after the iron is all melted, and others are cast at such intervals afterwards as may be judged proper. They are cast vertically, point downwards, in sand molds, and cooled rapidly.

Proof-bars are cast at different times while the metal is in fusion. They are broken in different places, and the condition of the iron is judged by the appearance of the several fractures. These fractures will exhibit various aspects, from white at the small end to dark gray at the large end; and the bars cast at the latter periods of the fusion will exhibit the white at a greater distance from the small end, and the mottle, bright and lighter shades will be found advancing towards the large end. This method, although much less reliable than that of an actual measure of density and strength, is convenient, because of its ready application at short intervals, while the iron is in fusion, and a practiced eye will soon be able to mark the progress of the changing quality of the iron, and to determine the proper time for casting the gun.

Effect of age on endurance.—In process of time, a gradual adjustment of the internal strains produced in cooling cast pieces takes place; like many other substances, iron possesses the property of accommodating itself to this.

Improvement in castings.—The principal improvement in the fabrication of cast-iron guns is General Rodman's process of cooling them as far as possible from the interior, and for this purpose casting them hollow. The design is to remedy the various defects of the old process; principally to obviate the tendency of solid castings to burst by their own initial strains, by reversing the process of cooling and shrinking described above. Since there would then be no force opposed to the contraction of the inner layers of metal, except the trifling cohesion of the liquid or pasty mass that they shrink away from, they would not be left in tension, and therefore they could not exert any power to pull the exterior layers into compression. The method employed is to carry off the internal heat by passing a stream of water through a hollow core, inserted in the center of the mold cavity before casting, and to surround the flask with a mass of burning coals to prevent too rapid radiation from the exterior.

Extensive trials have been made to test the merits of this plan, and the results show that cast-iron cannon made by it are not only stronger but are less liable to enlargement of the bore from continual firing, the surface of the bore being the hardest and densest part of the casting, and best calculated to resist pressure and abrasion.

Standard of quality.—Before proceeding to manufacture cannon in quantity, a *trial gun* may be made and exposed to extreme proof with

service charges. After undergoing this proof in a satisfactory manner, the trial gun should serve as a standard, and the proportions of the several kinds of metal used, and the methods employed in the manufacture should be followed in all respects in the fabrication of other guns.

With the trial gun should be cast a *sample gun*, or a cylinder of equal diameter, and at least half the length of the gun, from which test specimens should be cut and tested. The sample gun or cylinder should be of the same diameter as the guns to be made, and should be made under the same circumstances which are to attend the preparation of the iron for, and the casting and cooling of, the guns themselves. The object of the sample is to obtain specimens which have not been subjected to previous strain and vibration, as would be the case if taken from the fragments of the broken trial gun. For it is impossible to reason back to what would have been either the capacity for work, or work due to elasticity of an unstrained specimen, by knowing to what extent these properties were possessed by that specimen after it had been subjected to both strains and vibrations of unknown intensity and number. And although it is interesting to know to what extent these properties are possessed by the fragments of a worn-out gun, yet it would be of far greater practical utility and importance to know the value of these properties in the new, untried guns. Specimens thus obtained would afford reliable results, and in connection with the powder-proof, with service charges of guns cast at the same heat, these results would become standards.

DESCRIPTION OF THE PROCESS OF MANUFACTURING CAST-IRON CANNON UPON THE RODMAN PLAN.

All heavy cast-iron cannon manufactured for the land service of the United States are cast upon the Rodman plan. This plan consists in cooling the casting from the interior, and is effected by the insertion of a hollow core in the center of the mold cavity, through which a stream of water or current of air circulates, carrying off the internal heat. The radiation of heat from the exterior of the casting is meanwhile retarded by keeping the outside of the flask hot with surrounding fires. Extensive trials have demonstrated the superiority of cannon cast on this plan over those which are cast solid. The several operations in the manufacture of cast-iron cannon are *molding*, *casting*, *cooling*, and *finishing*.

Molding.

Molding is the process by which a cavity of the form of the gun is obtained by imbedding a model in sand and then withdrawing it.

The model of a gun (Plate IX, Fig. 1), technically termed the *pattern*, is usually constructed of wood made in as many sections and parts as may be necessary to admit of its being easily withdrawn from the mold.

The sections of the pattern for the breech and reinforce are made with diameters exceeding very slightly those of the finished gun, while the diameters of the sections for the chase are largely in excess. The breech section is provided with a cascabel for supporting the gun in the lathe while being turned and bored. The patterns of the trunnions are attached in their places by wooden pins, which can be easily withdrawn when it becomes necessary to detach the patterns. The several sections of the pattern for the body of the gun are made with a slight taper to facilitate their withdrawal.

The pattern for the chase of the gun is made considerably longer than

the required length of that part, to provide a "sinking-head" which, when the gun is cast, receives the scoria of the melted metal as it rises to the surface, and also furnishes the metal required to feed the shrinkage caused by the cooling of the casting.

The *sand* used for the molding composition should be principally of silex, very refractory, commonly called sharp-sand. When not sufficiently refractory it is vitrified by the high temperature of the melted metal, and protuberances are formed upon the casting which are removed with great difficulty.

To prepare the composition for use the sand is carefully sifted, then properly mixed and moistened with water in which clay has been stirred, or with the refuse of distillery wash called "returns."

Great care is required in securing the proper degree of cohesiveness in the composition, as it must be sufficient to enable the mold to preserve its form in handling, and not so much as to cause it to be injured by contraction in drying. It is considered sufficiently cohesive when it will retain its form when taken in a moist state and squeezed in the hand.

The same composition may be repeatedly used in molding, but as its cohesive property is destroyed by the heat to which it is exposed, it must be reprepared in the same manner as when first formed.

The mold is formed in a cast-iron case called a *flask* (Plate IX, Figs. 2 and 3), which is usually made in sections corresponding in number and length to those of the pattern. These sections consist of two pieces which, when united, are circular in cross-section, excepting two slight enlargements opposite each other for the formation of the channels or "side gates" for the metal to pass down. The pieces are flanged at the edges, fastened by bolts, and additionally secured by clamps over the flanges.

The trunnion sections of the flask are fitted with trunnion boxes which have movable plates at their ends for the purpose of introducing the trunnion patterns and facilitating the formation of that part of the mold.

The several sections are so constructed as to be united to each other in their regular order by means of clamps over the flanges at the top and bottom. (Plate IX.)

To form the mold the lower or breech section of the flask is placed upon an iron plate in an upright position, the corresponding section of the pattern introduced and centered; the space between the pattern and the flask filled with molding composition, which is rammed down in thin layers around the pattern until the section is completed. The patterns for the side gates and their branches for conveying the metal into the mold are introduced as the work progresses.

After the mold for the lower section is finished the next section of the flask is placed upon it and secured, the corresponding section of the pattern introduced, fitted with dowels, which enter the breech section and hold it accurately in place. The molding is continued with this section as with the first, and when completed it is lifted off, the pattern being left in the mold.

The third section of the flask, which is usually the trunnion section, is then placed upon the second and secured, and the pattern adjusted in the same way as before. The trunnion patterns are attached and the molding is continued. When this section is completed the pins attaching the trunnion patterns are removed and the patterns withdrawn.

The formation of the remaining sections is continued until the whole is completed, thus insuring a perfect mold throughout, free from irregularities at the junction of the sections.

Care is taken to sprinkle dry sand upon the surface of each section of the mold before continuing the work to prevent adhesion and to admit of the sections being separated without injury. As the work upon the respective sections is finished the patterns are withdrawn. If any portions of the mold are injured in the withdrawal they are repaired. The several sections are placed in the drying oven, where a moderate heat is kept up, until thoroughly dried. They are then removed from the oven, and a wash,* composed of German graphite, pulverized anthracite coal, and distillery returns, applied to the interior surface of the mold. The sections are replaced in the oven, and when dried removed, and a second coating of the wash applied while the mold is still warm. This wash is to produce a smooth, hard surface. It prevents the melted metal from mixing with the sand of the mold and forming protuberances on the surface of the casting. The sections of the mold are ready for use.

The *core-barrel* or *arbor* (Plate IX, Fig. 4) consists of a water-tight cast-iron tube, made sufficiently thick to withstand the pressure of the metal in the mold. Its length and diameter are such as to leave a sufficient surplus of metal in the bore of the gun to secure a good finish. It is constructed with a slight taper to facilitate its withdrawal after the casting. The lower end is rounded off and is fitted with several iron pins for securing the extremity of the rope, which is used as wrapping material in the preparation of the core; the exterior of the barrel is fluted from top to bottom to allow the escape of the gases generated by its combustion. Before being used the core-barrel is always subjected to a powerful water pressure to test its soundness. To prepare the core for casting, journals are fitted at its extremities. It is then placed in a horizontal position upon an iron truck, supported by the journals resting in bearings, and turned by a crank attached to one of the journals. It is first wrapped with white hemp rope so as to cover all of the exterior surface in contact with the melted metal in the mold. Over this a coating of molding composition is applied quite wet, wrapped with twine or wire to insure its adhering.

When the composition has partially dried another thin coating is applied and the surface rendered smooth and even by revolving the core in contact with a straight edge resting on the truck. The truck with the core is then rolled into the drying oven. When the composition is dried the core is removed from the oven and a coating of the same wash again applied. It is again replaced in the oven until thoroughly dry, when it is removed and the journals taken out. The one at the bottom is replaced by a tight fitting screw-plug covered over with molding composition. The top is fitted with a water-tight cap so constructed as to receive the conducting-pipes for the water, and is ready for use.

The *pit* (Plate XI), as usually constructed for the casting of guns on the Rodman plan, is cylindrical in form and is surrounded with a brick wall, built in offsets, affording supports for braces to steady the mold in position; grates are arranged around the circumference of the bottom for fires lighted immediately after the casting to retard the radiation of heat from the exterior of the mold. To retain the heat of the fires in the grates the mouth of the pit is covered with a close-fitting cover of boiler iron.

For furnishing air to the fires, flues are made opening into the pit below the grates, while near the top another flue, connecting with a

* Various materials have been used in the composition of this wash. Those above named have been found by experience to give the best results.

chimney, produces the necessary draught. If the pit has been out of use for any length of time, it is thoroughly dried by fires in the grates before placing the molds. To prepare the pit to receive the mold, the bottom is covered with a layer of sand. A heavy cast-iron plate is then laid down and carefully leveled. Upon this section the breech section of the mold is placed in an upright position. The other sections are successively lowered and secured in their places, the whole being braced from the sides of the pit to keep it in a vertical position. The core is then lowered into the mold of the gun. To center and secure it in position, a cast-iron frame, usually termed a "spider" (Plate IX, Figs. 5 and 6), is employed. The spider consists of a heavy ring supported upon three legs, each having a projection at the bottom fitted with an adjustable screw resting upon the upper flange of the flask. The core passes through the ring of the spider, is secured to it by bolts through the flange at the top of the barrel, and held firmly, so that any movement of the spider will produce a change in the position of the core.

To center the core, a long wooden rod is used, to the end of which a piece of board is fixed to hold a light. The length of this projecting board, previously determined, is the distance which the core should be, when in the center, from the mold at its maximum diameter.

Having adjusted the core in the mold by means of the screws in the legs of the spider, it is firmly secured in its position by clamps made to fit under the flange at the top of the flask and over the projections at the end of the legs of the spider. The fuel for the fires in the pit is arranged on the grates in readiness to be kindled.

CASTING.

The iron for the gun is melted in reverberatory air-furnaces (Plate X), two or three being sometimes required for casting the heavier guns. In these furnaces the draught is produced by high chimneys instead ot a blast, which is used in the cupola furnace. The metal for what is termed a "heat" is all placed in the metal chamber before the fire is lighted. The fuel, bituminous coal, is placed on grate bars in the fuel-chamber, and, when ignited, the flame passes through the metal chamber on its way to the chimney. The iron is melted by this flame without coming in contact with solid carbon at all, unlike the cupola furnace, where the fuel and iron are mixed together.

The furnace is prepared for charging by covering the bed of the metal chamber with a layer of sand evenly distributed and firmly packed. Boards are laid down, upon which the pigs of iron are piled. If a number of guns are to be cast from the same grades of iron, it is very important that the beds of the furnaces should be prepared in every instance as with the standard gun, as the treatment of a given charge of iron may be varied by the manner of dressing the bed of the furnace.

The different grades of iron to be used for the heat are weighed and piled in proper proportions in the metal chamber. Care should be taken to have the furnace perfectly dry throughout. When it has been out of use long enough to become damp, it should be dried by a fire in the fire-chamber before being charged.

When two or more furnaces are used in casting a gun, the tap-holes are connected by troughs with a reservoir called a mixing basin, in

Four and a half inch rifle-gun.—The 4.5-inch rifle-gun is made of cast-iron, cooled from the exterior, the great length and small size of the bore rendering the water-cooling process impracticable. Its form is similar to that of the 3-inch field-gun.

which the different charges are thoroughly mixed before entering the mold.

The furnaces being charged and everything in readiness, the fires are started and regulated so that the iron in all will be melted or "down," as near as practicable, at the same time. The length of time required to obtain complete fusion depends in great measure upon the state of the atmosphere and quantity of metal in the charge; it may vary from five to twelve hours.

When the charge is nearly down, wooden poles or iron rods are inserted in holes provided for that purpose in the walls of the furnaces, and the melted metal frequently stirred or puddled to bring the unmelted lumps in contact with the flame. As soon as the charge of a furnace is ascertained to be fairly down, specimens are taken out to determine whether the iron is sufficiently decarbonized or "high" to be in a proper condition for casting. These specimens are cast in green sand-molds and broken as soon as they become cold. The condition of the iron is indicated by the appearance of the fracture, and varies so much with different brands used that its determination is largely a matter of experience.

If the first specimens show insufficient decarbonization, the iron is kept in fusion still longer and the puddling process is continued. When it is found that the decarbonization has gone far enough, the puddling is stopped.

As the density and tensile strength of the iron depend in a great measure upon the highness to which it is brought, a correct decision is very important.

As soon as the melted metal in all the furnaces is found to be in proper condition for casting, the furnaces are tapped simultaneously and the metal conducted by troughs to the mixing-basin, where the several charges are thoroughly mixed. It then flows on through other troughs connecting with the side-gates of the mold, and, passing down, enters the mold cavity by the branches. These branches connect with the side-gates at regular intervals, and are so constructed that the metal enters in a horizontal direction toward the axis of the mold cavity. The surface of the metal, as it enters, is stirred to prevent the scoria from lodging; care should be taken not to give it a "swirl," which throws the lightest metal in around the core, where the heaviest and best should be. When the mold is filled, the tap-holes of the furnaces are closed, and the surface of the metal in the sinking head is covered with a layer of charcoal to prevent its chilling. For two or three hours after the casting, more metal is added at short intervals of time, to feed the shrinkage, by pouring from a ladle at the top of the mold as the surface sinks.

COOLING.

The water for cooling the gun is taken from a hydrant where the supply is constant and uniform, the connection being made by rubber hose. It is conducted into the core by means of a metallic tube which passes through a water-tight joint in the center of the cap and extends to within a few inches of the bottom of the barrel. The water consequently passes into the core at the bottom and ascends until it reaches the escape pipe and is discharged.

The flow of the water commences as soon as the furnaces are tapped, and is regulated to produce, half an hour after the casting, a certain change of temperature, about 25°, between entering and leaving the core. When this is effected the rate of flow remains constant until the core is removed.

As soon as possible after the casting the fire in the pit is kindled and kept up until the withdrawal of the core-barrel; it is allowed to die out gradually. Meanwhile the mouth of the pit is kept closely covered.

When the change of temperature of the outflowing water has become constant or nearly so, the core-barrel is withdrawn. To effect this, it is sometimes necessary to largely increase the flow of water for a short time, in order to contract the barrel enough to loosen it from the casting. As soon as this is effected the flow is stopped. The rope with which the barrel is wrapped takes fire from the heat of the casting and is consumed, leaving the barrel detached from the composition surrounding and allowing its withdrawal without difficulty.

As soon as the core-barrel is withdrawn the water is turned into the bore, being conveyed by the conducting pipe to the bottom and escaping by means of a tube cast into the gun head, entering the bore a few inches from the upper end of the casting. The rate of flow of the water through the bore is so regulated as to produce a change of about 100° between entering and leaving at half an hour after the removal of the barrel. It is then allowed to remain constant until the gun becomes cool. The time occupied in cooling by this process varies from four to six days, according to the size of the gun; for a 20-inch gun a longer time may be required.

In case the condition of the metal in the furnace before casting should indicate that a slower rate of cooling is desirable, the process of cooling by air is resorted to after the withdrawal of the core-barrel. The current of air is furnished by a rotary blower driven by steam or water power, and is conducted into the gun by a sheet-iron pipe, which extends to within a short distance of the bottom of the bore. Cooling by this process usually requires two or three days more than by the water process.

FINISHING.

When the casting has become cool it is hoisted out from the pit, the flask being first taken off. The molding composition adhering to the interior or exterior is removed as far as practicable by scrapers and chisels.

The casting is placed in a machine called a heading lathe (Plate XII, Fig. 1), where the greater part of the surplus metal of the chase is removed and the sinking head is cut off. From the latter a ring is also cut off next to the muzzle of the gun for the purpose of testing the initial strain, and from which specimens are afterwards taken for tenacity and density. To place the gun in the lathe, the square knob of the cascabel is fitted into the chuck attached to the machinery, which revolves the gun, while the sinking head is introduced into the "bonnet" which revolves in its bearing at the other extremity of the lathe. Both of these supports are provided with adjustable screws by means of which the gun is centered and held firmly in place.

The breech is adjusted by placing a sharp-pointed instrument in the tool rest and bringing it in contact with the surface of the casting near the maximum diameter, and, while turning the gun, the screws in the chuck are moved until coincidence of the line around the gun is obtained.

At the muzzle a bar of iron is laid upon blocks so that it shall be just inside the bore and nearly in contact with the interior surface. As the gun turns, the distance between this point and the metal of the bore is observed and equalized approximately by the screws in the bonnet.

A wooden disc, turned to fit the bore accurately, bearing a string at-

tached to its center, is then pushed to the bottom of the bore and made to assume a position in a plane perpendicular to its axis. The string from the center of the disc is long enough to reach some distance outside of the muzzle, the outer end being made fast to an upright at the same height as the inner end or center of the disc. The string is now stretched perfectly taut and the gun again turned, a square being placed upon blocks about one foot in front of the muzzle close to the string, and, as the gun revolves, the distance, if any, which the string deviates from the square is observed and corrected by again moving the screws in the bonnet. When properly centered, the string will remain in the same position in the square and be the same distance from the interior surface of the gun throughout an entire revolution, showing that the axes of the gun and lathe coincide.

With the hollow-cast gun it is necessary that it should be centered from the bore, as it sometimes happens that the axis of the bore and casting do not coincide. The gun being centered, all the measurements necessary for a proper commencement of the turning are made.

The turning of the gun commences near the muzzle. The rest in which the turning tool is placed is so constructed that it can be moved either parallel to or at right angles to the axis of the gun. The tool is brought in contact with the surface of the gun at the desired point, the metal being turned off as the gun revolves. In this way a series of narrow cuts are made in the chase at short intervals, extending in depth to within about 2 inches of the required exterior diameter of the gun. The intervening rings are then broken out with wedges, and the portion of the chase next the muzzle is turned down to the finished dimensions. Meanwhile the cylindrical part of the cascabel is turned down slightly to form, with the finished part of the chase, bearings for the gun when transferred to the boring lathe. The cuts at the muzzle for removing the sinking-head and test-ring are next made. When these cuts have reached a sufficient depth to admit of the separation, the gun is taken out of the lathe and placed upon skids and the bonnet is removed from the sinking-head. The ring and head together are then separated from the gun by inserting wedges at the muzzle, and the ring is afterwards wedged off from the head. The gun is next placed in the boring-lathe (Plate XII, Fig. 2), in which it is supported by bearings at the chase and neck of cascabel. Its rotation in the lathe is effected by securing the square knob of the cascable in the chuck attached to the revolving machinery, in the same manner as in the heading lathe.

To adjust the gun the boring rod is first introduced a short distance into the bore, and the space between its exterior surfaces and the gun at the muzzle is observed. For this purpose a thin wooden gauge is used, pointed at one end and having a notch at the other, which takes the outer surface of the gun at the muzzle—the gauge being laid on the face of the muzzle and, therefore, perpendicular to the axis of the bore. As the gun revolves the distance above, below, and on either side is observed, verifying the concentricity of the axis of the gun at the muzzle.

The adjustment is completed at the breech by slackening the bolts of the cascabel bearing, leaving it free to move on the ways, and should any lateral motion be perceptible it is corrected by adjusting the screws in the chuck, after which the concentricity is complete from breech to muzzle.

In boring, the tools or cutters are fitted into a cylindrical block called a "head," which is secured to the end of the boring-rod. As the gun revolves in the lathe, the boring-rod is made to advance by machinery until the cutters reach the bottom of the cylindrical part of the bore.

From three to five cuts are usually required to secure a perfectly straight bore and enlarge it to its required diameter; the last one being made with a finishing tool or reamer. The bottom of the bore is then finished with tools of the required shape.

During the process of boring the turning continues, and the exterior is finished except the trunnion section and the extremity of the breech where the cascabel attaches. The cascabel is turned down in front of the bearing so that it can be broken off when no longer required. To insure a smooth surface in the bore, the work upon the exterior of the gun is suspended while the finishing tools are being used.

The boring being completed, the dimensions of the bore of the gun are verified before removing it from the lathe. If found to be correct, the gun is removed and placed in the trunnion lathe (Plate XIII), where the trunnions are turned down to the finished dimensions. When adjusted in this lathe the axis of the gun is in a horizontal plane, the cascabel being supported by the breech center, and the chase by the muzzle bearing. The trunnion-head consists of a hollow shaft in which are placed the cutters for turning the trunnions. It is supported upon bearings which rest upon ways at right angles to the axis of the gun. These bearings are of such a height as to bring the axes of the trunnion-head and gun in the same horizontal plane.

In turning the trunnions the gun remains stationary while the trunnion-head revolves about the trunnion. The cylindrical surface is first finished, the shaft moving towards the gun and its speed being regulated as circumstances require. To finish the face a broad cutter is used which removes a thin chip nearly equal in width to the semi-diameter of the trunnion. A small spur is left by this tool at the center of the trunnion which is afterward chipped off by hand. When one trunnion is finished, the gun is turned over and the other is finished in the same manner.

The metal in excess between the trunnions is removed by the planing machine (Plate XIII) which is placed on the side of the lathe opposite the trunnion-head. This machine is so arranged that the bar in which the cutter is secured moves forward and back in a horizontal plane, carrying the cutter over that portion of the gun between the trunnions which has not been turned down. The cutter works upon a pivot in the bar, by means of which it cuts only while moving to the rear, the gun being turned the width of the cut after each passage of the planing bar. The proper direction is given to the cutter by means of a guide attached to the planing bar which moves in a groove of the required curvature.

After the planing is finished, the gun is removed from the lathe and placed upon skids and the cascabel is broken off. The breech, rimbases, and sight-mass are then finished by chipping off the surplus metal by hand.

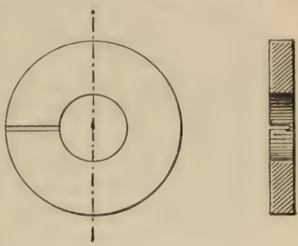
The vent is drilled by means of a hand-drill arranged to work in an iron frame firmly secured to the gun.

INITIAL TENSION—HOW DETERMINED; ITS OBJECT; ITS EFFECT, AND PROPER LIMIT.

A ring, about three inches thick, is taken off the gun-head parallel to the face of the muzzle, and as near thereto as practicable. This ring is not reamed out or turned upon the exterior, but is a section of the rough casting. When two rings are taken from the same head, the one nearest the muzzle is marked number 1, the other number 2. In a 15-inch

gun the distance of ring No. 1 from the face of the muzzle measured to the center of the ring is 3,7 inches; and of ring No. 2, 7.5 inches.

In a 10-inch gun the distance of No. 1 is three inches; of No. 2, $6\frac{5}{8}$ inches. Each ring is cut through by planing a groove 0.5 inch wide from the exterior to the core until the initial strain breaks the unplaned part, and the ring springs open. The width of the groove at the exterior is now measured, and its increase over 0.5 inch divided by the original circumference of the ring will be the extension per inch of the metal on the exterior. This extension per inch is then compared with the extension per inch obtained by actual experiment with a specimen of the same iron, and the corresponding stress required to produce it will be the initial tension.



For example, the ring from a 15-inch-gun head is, say, 38 inches in diameter; the width of the groove before the bursting of the ring is 0.5 inch, and afterwards 0.65 inch, showing a total extension on the exterior of 0.15 inch, then

$$\frac{0.15}{\pi 38} = \frac{0.15}{119.38} = .00127$$

for the extension per inch of metal on the exterior.

Upon examination of the tests of this metal, we find the stress corresponding to this extension per inch to be 20,000 pounds per square inch, which will be the initial tension of the ring, supposing the iron to possess the same tenacity and elasticity, and that the breaking of the ring entirely relieved it of strain, which it cannot probably do.

To illustrate the effect of the initial strain upon the strength of the gun, let us suppose that the initial strain of extension upon the exterior of a gun one caliber thick—and of which the tenacity of iron is 30,000 pounds per square inch—is 15,000 pounds per square inch, the metal at the surface of the bore will be subjected to a compressive strain of 15,000 pounds per square inch.

Now if we suppose the tangential strain due to the action of a central force, such as fired gunpowder, to decrease directly as the distance from the axis of the bore increases, and that an interior force just sufficient to relieve the metal at the surface of the bore from compression has been applied, then will the exterior of the gun be brought to a strain of extension of 20,000 pounds per square inch. Now increase the interior pressure of gas until the metal at the surface of the bore is under a tensile strain of 30,000 pounds per square inch, and the tensile strain of the metal on the exterior of the gun will be increased to 30,000 pounds per square inch also, and the whole thickness of the walls of the gun would be brought to the breaking strain at the same instant, which is the object of initial strain. But in practice we know that the strain due to a central force diminishes in a higher ratio than directly as the distance from the axis, and this would require an increase of initial strain in order to bring the outer portions of metal to the breaking point at the same time, while on the other hand the fact that a given increase of load or strain will produce a much greater extension when applied to a specimen near to its breaking strain than when applied to the same specimen when strained within, or even considerably above the limits of its permanent elasticity, causes the maximum resistance of a gun, having too little

initial strain, to approach more nearly than it would otherwise do to what its maximum resistance would be with a proper initial strain.

The law of diminution of tangential strain from the bore outward in a gun is not and cannot be accurately known, nor, therefore, can the exactly proper initial strain be determined.

But, as the foregoing reasoning shows, after the initial strain shall be equal to that estimated on the hypothesis that this strain is inversely as the distance from the axis of the bore, it may vary considerably above that point without affecting to any considerable degree the maximum resistance of the gun; and we therefore know that we are safe in fixing the initial strain at, or a little above that which the law of diminution of strain as the distance from the axis increases, would give.

OBSERVATIONS ON CASTING GUNS BY THE RODMAN METHOD.

The initial tension-rings for Rodman guns, on being planed through, should open on the exterior 0.25 inch for 20-inch guns; 0.17 inch for 12-inch rifles; 0.15 inch for 10-inch rifles. The properties of iron employed and the rate of cooling should be so regulated as to produce these openings. If the rings do not open sufficiently, add more water and fire longer, which will insure a higher tension. If the rings open too much, diminish the quantity of water and the length of time the fire is kept up in the pit. The gun should not in any case be "steamed"; but, if necessary, the water may leave the casting at 200° or 205°. The more rapid the cooling the higher the iron, and the more rapidly the interior is cooled over the exterior the greater the tension. If a higher density of the metal is required a less fire will be required in the pit.

Cold iron should not be put into a pool of melted iron. If the iron is not high, it should be kept in fusion and evenly stirred till a satisfactory result is obtained.

In planing through the rings for initial tension they should be so clamped in the planing-machine that one-half should be free to spring open when the thickness is so far reduced by planing that the initial strain will break the metal thus left. In other words, the planing should be continued till the ring parts. The thickness of the metal broken should be accurately measured, as also the amount of opening in its exterior.

For 10-inch guns the thickness of the broken part of the ring should be about one-tenth of the whole thickness of the ring. Should it be less, more water and a longer continued fire in the pit will correct the defect.

The amount of initial tension on the exterior, which General Rodman thought should obtain in a properly constructed gun, was about one-half the ultimate tenacity of the metal.

Bloomfield gun-iron, when employed in 20-inch guns, should be so far decarbonized as to have a density of 7.24 to 7.26, with a tenacity of 32,000 pounds. When employed in 12-inch rifles it should have a density of from 7.26 to 7.28, with a tenacity of 32,000 pounds. When employed for 12-inch shot to be chilled at the point it should have a density of from 7.32 to 7.35.

Richmond gun-iron, when for 10-inch rifles, should have a density of from 7.28 to 7.30, with a tenacity of 32,000 pounds.

In the manufacture of 4.5-inch siege rifles the application of the water-cooling process is impracticable, owing to the great length and small size of the bore. These guns are, therefore, cooled from the exterior. The best quality of gun-iron should be employed in these guns, with a

density not to exceed 7.25, say from 7.22 to 7.25. The guns should be cooled slowly in covered pits.

INSPECTION AND PROOF OF ORDNANCE.

(Plates XIV, XV.)

Smooth-bore cannon presented for inspection and proof are placed on skids for the convenience of turning and moving them easily. They are first examined carefully on the exterior to ascertain whether there be any flaws or cracks in the metal, whether they be finished as prescribed, and to judge, as well as practicable, of the quality of the metal. They must not be covered with paint, lacker, or any other composition. If it be ascertained that an attempt has been made to conceal any flaws or cavities by plugging or filling them with cement or any substance the gun is rejected without further examination. After this preliminary examination, the inspector proceeds to verify the dimensions of the piece. The interior of the bore is first examined by reflecting the sun's rays into it from the mirror, or, if the sun be obscured, by a lighted candle or a lamp placed on the end of a rod and inserted into the bore. The *cylinder gauge* screwed on the staff is then pushed gently to the bottom of the cylindrical part of the bore and withdrawn; it must go to the bottom or the bore is too small.

The bore of the piece is then measured with the star-gauge, beginning at the bottom. Measurements should be made at intervals of $\frac{1}{4}$ inch to the front of seat of shot, and at intervals of 1 inch from that point to the muzzle. In rifled guns the measurements are taken from land to land, and afterwards from groove to groove, the head of the star-gauge being fitted with the suitable "guide" to insure the proper position of the measuring points.

The *position of the trunnions* with regard to the axis of the bore and to each other is next ascertained.

To verify the position of the axis of the trunnions.—Set the trunnion-square on the trunnions, and see that the lower edges of its branches touch them throughout their whole length; push the slide down till it touches the surface of the piece, and secure it in that position by the thumb-screw; turn the gun over, and apply the trunnion-square to the opposite side, and if, when the point of the slide touches the surface of the piece, the lower edges of the branches rest on the trunnions, the axis of the trunnions is in the same plane with the axis of the bore; if they do not touch the trunnions, their axis is above the axis of the bore by half the space between; and if the edges touch the trunnions and the point of the slide does not touch the surface of the piece, their axis is below the axis of the bore. If the *alignment of the trunnions* be accurate, the edges of the trunnion-square will fit on them when applied to different parts of their surface; their diameter and cylindrical form and the diameter of the rimbases are verified with the trunnion-gauge.

To ascertain the length of the bore.—Screw the *guide-plate* and *measuring-point* on the cylinder staff and push them to the bottom of the bore; place a *half-tompion* in the muzzle and rest the staff in its groove; apply a *straight-edge* to the face of the muzzle and read the length of the bore on the staff. The *exterior lengths* are measured by the *rule* or by a profile, the accuracy of which is first verified; the *exterior diameters* are measured with the *calipers* and *graduated rule*. The *position of the interior orifice of the vent* is found from the mark made on the *rammer-head* by the *vent-gauge* inserted in the vent, while the rammer-head is held against the bottom of the bore. Two impressions are taken. The posi-

tion of the exterior orifice of the vent is also verified. The *vent* is examined with *gauges* and with the *vent-searcher* to ascertain if there are any cavities in it.

All smooth-bore *bronze* ordnance should be bored under size from .04 to .05 inch, and, after proof, reamed out to the exact caliber. *Whitish spots* show a separation of the tin from the copper, and, if extensive, should condemn the piece. A great variation from the true weight, which the dimensions do not account for, shows a defect in the alloy.

In *mortars*, the dimensions of the *chambers* and the *form of the breech* may be verified with *patterns* made of plate iron.

After the *powder proof* the bore is washed and wiped clean, and the bore and vent are again examined, and the bore remeasured. The results of each of the measurements and examinations are noted on the inspection report against the number of the gun.

A proper discretion must be exercised in the inspection of ordnance; such slight imperfections as do not injure a piece for service may be disregarded, whilst the instructions should be strictly enforced with regard to defects which may impair its utility.

PROOF OF ORDNANCE.

Gunpowder for proving ordnance should be of the best quality of the kind used in the gun to be proved, giving not less than the standard initial velocity; it should be proved immediately before being used, unless it shall have been proved within one year previously, and there be no reason to suspect that it has become deteriorated.

The *cartridge-bags* are made of woolen or raw silk, the full diameter of the bore or chamber. They are filled by weight.

The shot must be smooth, free from seams and other inequalities that might injure the bore of the piece, and they must be of the true diameter and weight given in the tables.

Guns and *howitzers* are laid with the muzzle resting on a block of wood, and the breech on the ground or on a thick plank, giving the bore a small elevation.

Bronze pieces are mounted on appropriate carriages or beds.

Mortars are mounted on strong wooden frames or iron beds, at an elevation of 45°, supported by the trunnions.

Each piece shall be fired two rounds with maximum charges and projectiles.

Should any of the guns proved at one time fail to sustain the above proof, the remainder shall be rejected, if made of the same metal treated in the same manner.

The bore, vent, and the exterior surface of every piece which is approved, should be well covered with sperm oil immediately after the inspection.

8-INCH CONVERTED RIFLES.

(Plates XVI to XXVII.)

Two plans of conversion of our 10-inch smooth-bore cast-iron guns into 8-inch muzzle-loading rifles, by lining with coiled wrought-iron tubes, find place in our service; one by "muzzle," and the other by "breech" insertion.

The parts in general of these converted rifles are:

First. The old casing bored out to the exterior diameter of the inserted tube.

Second. The rifled coiled wrought-iron tube.

The mode of manufacturing the iron for the tubes is first treated of, followed by a description of those operations common to the construction under both systems.

A description then follows in which those details are given which are peculiar to each system.

MANUFACTURE OF THE BAR-IRON.

The bar employed up to the present time in the fabrication of tubes for conversion has been manufactured at the Ulster Iron Works, Saugerties, N. Y. The pig, from which the iron is produced, is derived chiefly from the Lake Champlain magnetic ores and from some of the hematite ores of Pennsylvania, the suitable proportions of kind and grade to yield a satisfactory metal, being the result of much careful experiment.

The various operations of puddling, rolling, &c., differ in no particular respect from the ordinary methods employed, except in the greater care exercised to secure a high standard for the quality of the product. A brief notice here will therefore suffice.

The charge of pig-iron is first heated to redness by the waste heat from the reverberatory furnace, and is then thrown into the hearth along with a quantity of cinder. The charge consists of 448 pounds, the yield of blooms amounting to about 95 per cent. of the metal charged; the amount of coal consumed is 2,375 pounds per ton of puddle-bars, and the time occupied from the charging of the furnace to the withdrawal of the puddle-balls is about $1\frac{3}{4}$ hours.

The process in the furnace is what is termed the "boiling process"; and the regulation of the draft during this period is an operation requiring great care and good judgment, as upon it the quality of the bar-iron will, in a great measure, depend. It is important that the iron designed for gun-tubes shall not be too "dry" (deficient in cinder), as such an iron crumbles under a high heat, and, at best, welds but imperfectly. On the other hand, the presence of any considerable quantity of cinder indicates an insufficient "working," besides furnishing for the bore of the gun a material that is not sufficiently homogeneous and compact to resist well the eroding action of the powder-gases. The puddle-bars are formed under the hammer into blooms about 18 inches long by 4 or 5 inches square, and weighing about 100 pounds each. The blooms before cooling are passed between the rollers—both roughing and finishing—and result in what are termed "muck-bars"—long, flat bars from 2 to 4 inches wide and $\frac{5}{8}$ inch thick.

The "muck-bars" are cut up and piled. The piles are then placed in the furnace and raised to a white heat, when they are subjected to a succession of rollings, by which they are converted into bars about 23 inches long and about $\frac{1}{2}$ inch thick. Each time, before being passed between the rollers, the piles are turned one-quarter round, so that the compression of the metal takes place in directions that are alternately parallel and perpendicular to the layers.

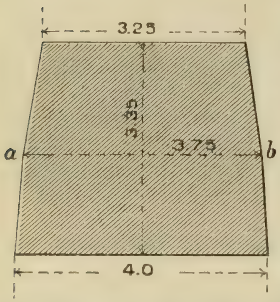
The operation of cutting, piling, and rolling are then repeated, and the resulting bar or plate cut into lengths of 53* inches, and piles made about $9\frac{1}{2}$ inches high by 7 inches wide for the final rolling. The top and bottom plates of these last piles are about $\frac{3}{4}$ of an inch thick, while the intermediate plates are $\frac{1}{2}$ inch thick.

At this stage the piles are passed between the rollers, at first with

*The dimensions and weights given in this description of the "rolling" of the bar-iron refer to that used in the construction of "muzzle-insertion" tubes, and would, of course, be modified for iron of different size.

the layers horizontal, but are afterwards so manipulated that the corners of the pile shall take the groove in the rollers. The precaution is taken, in heating the piles, to separate slightly the successive layers, in order that the heat may more readily penetrate the mass; and both in piling and rolling the iron it is important that the direction of the fiber should be always preserved the same. In the finished bar the elementary plates stand parallel with the depth—the position most favorable to their final consolidation in the subsequent process of coil welding.

The cross-section of the bar used for muzzle insertion tube is hexagonal in form (as shown in the figure), to compensate for the changes in form incident to the process of coiling.



By making the bar simply trapezoidal in cross-section, it was found that, in cooling, the sides became concave, thereby forming a pocket, which, in the subsequent process of uniting the folds of the coil, served as a receptacle for cinder, and proved an obstacle to perfect welding. In order to avoid a feature so objectionable, the shoulders *a-b* were added, whence a supply of metal can be drawn to fill up the concavity of the sides. The ends of the finished bar are cut off to where the material is thoroughly welded and perfectly sound, the greater length being taken from the end which was nearest the furnace door, as being the colder end.

The bar is now ready for shipment to the foundry. Specimens of each lot are tested for the purpose of ascertaining the physical properties of the metal.

Following is a tabular comparison between the Ulster tube-iron and the Risdale tube-iron; the latter being that employed by Sir William Armstrong & Co., at the Elswick Works, in the fabrication of gun-tubes and coils:

Material.	Tensile strength, pounds per square inch.		Elongation per inch at breaking.		Elastic limit, pounds.		Density.	
	Ulster.	Risdale.	Ulster.	Risdale.	Ulster.	Risdale.	Ulster.	Risdale.
Bar iron (along its fibre)	52, 000	52, 534	0. 303	0. 299	22, 500	24, 000	7. 664	7. 690

The above were determined by taking a mean of five tests of the Ulster and two of the Risdale iron.

The following are analyses of samples of the same irons:

	Sample marked English.	Sample marked American.
Copper	0.0558	0.0104
Nickel	0.0275	0.0210
Sulphur	0.0018	0.0027
Phosphorus	0.2480	0.2025
Manganese	0.0198	0.0194
Silicon	0.1479	0.1582
Cobalt	0.0512	0.0495
Carbon	0.0230	0.0155
Iron	99.5400	99.5000
Cinder	0.0010	0.0010
	100.1160	99.9802

WELDING THE BARS.

To prepare the bars for welding they are sorted in pairs, and the ends to be united shaped for scarfing as illustrated on Plate XVI. At the same time the other ends are tapered by heating and hammering, and an eye and shoulder (*a b*) formed for purposes connected with the operations of "coiling."

The V scarf, by affording a firm grasp to the ends and exposing a large surface for welding, is thought to insure a strong joint; yet so great is the strain thrown upon the bar while being coiled, that separation has been known to take place at that point.

The welding is readily performed by means of a "hollow" fire and an adjacent steam hammer. The joint is subjected to three heats. At the first heat the bars are "butt-welded" by means of sledges; at the second and third heats, the joint is "lap-welded" by the steam hammer, the original cross-section being afterwards restored by interposing a tool of the necessary shape between the bar and the hammer. While in the fire, one end of the bar abuts against a heavy timber, and the other end is repeatedly struck with a sledge to close and "upset" the joint.

COILING.

The heating oven is shown on Plate XVII, in plan, section, and elevation; Figs. 1, 2, 3, and 4.

	Feet.
Total length of oven	78
Height	30
Width	42

The grates and ash pits, seven in number, are arranged along one side and the draught enters under the grates. The blower is worked by the engine that revolves the coiling apparatus. The number of fires employed at any one time depends upon the length of the bars to be heated. About ninety bushels of anthracite coal a day are consumed in each grate. At the rear of the oven is a roller-way, upon which the bars are inserted into the oven; an operation which is facilitated by a slope given to the oven and trestle-work.

The bars are pushed into the oven as far as possible, and then are drawn into place by means of a long iron hook introduced from the front,

fastened to the eye in the front end of the bar and worked by the windlass of a steam-crane.

It requires about three hours to heat the oven, and, after that, about one hour to heat the iron to a bright redness—the temperature required.

The oven has a capacity for eight bars of the size used for muzzle insertion tubes; but, to secure greater facility in handling, more than four are seldom heated at once.

The coiling apparatus is shown on Plate XVII, Fig. 5; *a* is the mandrel, slightly conical in form, on which the bar is wound; *b* is the roller-guide over which the bar passes; *c* is the sliding-guide which regulates the spiral of the coil; at *d* is the steam-piston which communicates the motion. On the mandrel is an iron disk, *e*, through which is inserted a key, *f*, and the end of the bar is attached to the mandrel by passing between it and the key, and hooking over the latter by means of the shoulder on the bar. In this position the narrow side of the bar is in contact with the mandrel.

The apparatus having been put into gear, the mandrel revolves, winding the bar around it.

To remove the coil, the apparatus is thrown out of gear, the cap-squares of the mandrel are removed, and, by means of the steam-crane standing immediately in rear, the mandrel is unshipped and swung round. The coil is then started by driving in wedges between the end of the coil and disk, *e*, after which it is easily removed.

After coiling, the cross-section of the bar is slightly concave on the exterior and convex on the interior of the coil, while the distance between the folds are less on the interior than on the exterior.

It requires about one hour to coil four bars.

WELDING THE COILS.

When removed from the mandrel the ends of the bar project out from the coil, and the folds are very open, varying from $\frac{3}{4}$ to $1\frac{1}{4}$ inches on the exterior. The ends are, therefore, heated and hammered round to conform to the curvature of the coil. The next step is to close the folds and to weld them together. For these operations there are provided two cast-iron tubes, termed "welding-pots" (Plate XVIII, Figs. 1, 2, 3, and 4). These pots are cylindrical without, but slightly conical within, and are of two sizes, the diameter of the smaller being about one inch larger at the bottom than the finished diameter of the tube, and the diameter of the other $\frac{3}{8}$ inch larger. In connection with the pot is used a short iron cylinder, termed the "cheese" (Fig. 6), about 9 inches in height and somewhat smaller in diameter than the pot, which receives directly the impact of the hammer after the first blow has compressed the coil within the limits of the pot. The coil is first placed on its side and heated to redness in an ordinary reverberatory furnace, and then transferred, by means of a porter-bar suspended from a crane, to the smaller welding pot, in which it is simply pressed under the hammer. The effect of this operation is to close the folds along the surface of the bore. The porter-bar is provided with a heavy sliding counterpoise to facilitate handling it.

In order to avoid weak or imperfect welding of the folds, it is desirable that the process should commence at the interior surface of the coil and progress gradually outwards, thus leaving to the last an open joint at the exterior for the escape of the cinder squeezed out in the operation. This end is secured with large bars by the particular form of cross-sec-

tion given to the bar, and by the precaution taken of first closing the folds along the interior surface before attempting to weld them.

The coil is now replaced in the furnace and brought to a welding heat. It is then removed to the smaller welding-pot, stood upright under the hammer, the "cheese" placed on top of it and hammered until the latter sinks to a certain mark chalked upon it. The pot is then turned over on its side and the coil withdrawn by means of blocks and tackle. The coil is then turned end for end, and quickly returned to the furnace; and, after being brought again to welding heat, the same operation of hammering is repeated, using, however, the larger pot.

The whole operation of coil-welding a single section takes from 2½ to 3 hours.

The hammer employed in welding the coils is an 8-ton steam-hammer.

On Plate XIX, Figs. 1, 2, and 3, are illustrations of the coil * at the following stages of its fabrication, viz: After being removed from the mandrel of the coiling apparatus; after the closing of the folds along the surface of the bore, and after the welding of the folds.

The length of the coil, after closing the folds, is about 4½ feet, and the exterior from 13 to 13½ inches. After being withdrawn from the large pot, the length is about 3 feet; the exterior diameter about that of the large pot, and the interior diameter from 5 to 7 inches. The width of fold in the coils for the A tube is now about 2.75 inches, while in those for B tubes it is about 2 inches.

NOTE.—In England the process of coil-welding differs as follows from the above: "The coil having been subjected to a 'welding heat,' is placed vertically under the steam-hammer and receives a few smart blows to weld the folds. It is then thrown on its side, and being gradually turned, is hammered (or patted) all round to straighten it. It is then raised vertical again, and a punch or mandrel—rather over half the length of the coil and a little larger than its interior diameter—is hammered down its own length. The coil is next placed on its side and hammered round that half of its length, thus being made very compact, and large enough to let the mandrel fall out. After this, the coil is again raised vertical and the mandrel forced in the opposite end, and the process repeated. The reason a long mandrel is not forced through the whole length of the coil is that it would tend to separate the folds. The coil is replaced (upright) in the furnace for the second heating, and much the same process is followed, to render the ring more consolidated as well as more shapely."

By the American process there seems to be no tendency whatever to separate the folds during any part of the operation. The coil is withdrawn from the welding pot by connecting the tackle with an iron rod which passes through the interior of the coil, and is held by a key at the bottom, so that the strain is transmitted to that point.

WELDING THE SECTIONS.

After welding the folds the coils are extremely rough and uneven on the interior; they are therefore removed to the shops, where they are rough-bored to within 0.75 inch of the true diameter of the tube. The exterior is comparatively smooth and cylindrical.

To unite two or more coils to form a tube, the ends are faced and reciprocally recessed; that is, a projection is formed at one end of the coil, while a recess is bored in the corresponding end of another coil (Plate XVIII, Fig. 5). The height of the projection is a little greater than the depth of the recess, in order to secure a close joint on the interior. The recess is then expanded by heat and shrunk over the projection, so that the two coils are sufficiently stuck together to admit of being put in the furnace for welding. An iron rod, with a key at one end and a nut at the other, is passed through the sections and screwed fast to prevent a separation of the sections in shrinking.

* This refers to a section for a muzzle-insertion tube.

The furnace for welding the section is so constructed that an intense heat shall act only upon the joint. The butt-welding is performed by means of a powerful screw-press.

The furnace and welding apparatus are illustrated on Plate XX. The tube is placed in the furnace by means of the crane and a porter-bar; the bars *a a* are then raised on the supporting props *b*; the cross-head *c* and the screw *d* adjusted to the end of the tube, and the wedges *e* inserted. The furnace is then entirely closed around the tube and the draught turned on. It requires from two to three hours (depending upon the condition of the atmosphere) to raise the temperature of the metal on the interior of the tube to a welding heat. This fact is ascertained by examining the outside of the tube within the furnace, and the inside of the tube through a hole pierced through the cross-head *c*, and covered with a plate of mica.

A welding heat being obtained, the screw, which works in the cross-head *f* as a nut, is tightened by means of the handle *h* till the tube is compressed longitudinally ½ inch. The tube is then turned half around, the heat renewed for about ten minutes, and another turn given to the screw, by which a further compression of ½ inch is obtained. The props are then knocked away, the bars and cross-head fall down, and the tube, which is considerably bulged at the joint by the compression it has undergone, is removed on the porter-bar to the steam-hammer, patted into shape, and lap-welded. Sand is thrown on the joint during this operation to protect the iron.

The face of the hammer, as well as the top of the anvil, is semi-cylindrical, to conform to the shape of the exterior of the tube.

A rule is then applied, touching at points *a a* (Plate XVIII, Fig. 5), equally distant from the axis, to ascertain if the tube is straight; if not, it is at once straightened under the hammer before cooling.

Two sections being thus welded together, another is added in a similar manner; and finally one more section, which completes the tube.

The furnace used has a capacity for about 1,500 pounds of coal—anthracite coal being employed—and is so arranged as to consume its own gases. The amount of coal consumed in welding thirteen sections is about 6,900 pounds.

It requires ten hours to heat up the furnace when cold, when working daily about four hours. The fire is always replenished during an interval when the tube is withdrawn so as not to interfere with the heating. While in the furnace, should the joint become unequally heated, sand is thrown in upon the hotter part to equalize the temperature.

FABRICATION OF THE TUBES.

The A or main tube is composed of four sections or short tubes welded together, each section consisting of two bars, which are united end to end before coiling.

The B tube and jacket for tubes, designed to be inserted from the muzzle and from the breech, respectively, have now to be made. Their construction, which forms the principal feature of distinction between the two plans of conversion employed, will be subsequently described.

The breech-cup is made from a solid forging stamped into shape under the steam-hammer. The collar for securing the tube at the muzzle is made of tube-iron, fagotted and hammered out to the proper size. It is then bent over a mandrel, and the ends welded together.

The tube and its accompanying parts have now to be transferred to the "finishing shop" and prepared for insertion.

The power is distributed from the engine by the shafting, which consists of rods of iron running the length of the workshop, and which, by means of attached pulleys, transmit the power used to the different machines. The motion is transferred by means of belts or bands, ordinarily of leather, passing from those above mentioned to similar pulleys. These belts may run direct to the machines themselves, but more usually pass over an intermediate pulley attached to the counter-shafting; this is placed below the "main shafting," and carries pulleys of different sizes, and idle pulleys, by the former of which the rate of speed may be varied; by the latter the machine brought to rest without interfering with the motion of the main shafting. It is frequently necessary to reverse the motion of a machine, and this is effected by using a belt which is crossed between the pulleys over which it passes.

While belts are generally employed to transfer rotation from one axle to another where these are at a considerable distance apart, when they are very near each other toothed wheels are used of different form and size, according to the relative positions of the axles and the work the machine is required to perform. When the axles are parallel "spur wheels" are used, in which the teeth project radially from the circumference. When the axles are not parallel "bevel wheels" are used, in which the teeth are formed on the surface of a cone. Miter wheels belong to the latter class, and are used when the axles are at right angles, and frequently for simply changing the direction of motion.

To enable the various machines to perform the work required of them, the rotary motion of the shafting must be converted into rectilinear and other motion. Circular motion is changed into rectilinear by means of "cams." Rectilinear motion is converted into circular by a crank, or by means of a pawl and ratchet wheel, the pawl being on a jointed arm worked by a cam; the former gives continuous, the latter intermittent motion.

The A tube and B tube or jacket are now bored, turned, and otherwise prepared for assembling; the tube turned down for the reinforcing tube and muzzle-collar; the breech-cup turned on the inside and a screw-thread cut on the outside, and the muzzle-collar bored out and a screw-thread cut on the exterior. The gun-casing is also bored to receive the tube, and a recess and screw-thread cut on the muzzle-collar.

Much of this work, including that of preparing the sections for welding, is performed in an ordinary lathe. As the gun-bed, in which the gun-casings are bored and the heaviest work generally done, is a modification of the same machine, an outline description is here given.

Fig. 1, Plate XXIII, represents an ordinary slide-lathe, in which nearly all the desired operations can be performed: *a* is the "head-stock"; *b* the bed; *c* the "back-center"; *d* the self-acting "slide-rest"; *e* the "face-plate" or "chuck," by which the article operated upon is attached in position; *f* is the "back-shaft" or "feeding-screw," which carries a short worm movable along the length of the shaft, in which works a "worm-wheel" attached to the "slide-rest." By means of a pinion gearing into rack (*g g*) running along the lathe-bed, the slide-rest can be traversed by hand.

The work performed in such a lathe requires much power, and, as a consequence, low speed. The power received from the main shafting is first reduced by the counter-shafting, and afterwards to a different degree by the different steps of the conical pulleys attached to the "head-stock." The face-plate is fastened to a mandrel, which passes through the conical pulley and is independent of it.

The motion of the conical pulley is transferred in a reduced form to

the face-plate by the gearing. When it is desired to give the face-plate the same rate of motion as the conical pulley, the two can be bolted together, and the intermediate gearing thrown "out of gear."

The cutting-tool is attached at any inclination to a holder, which can be moved by hand on the slide-rest, longitudinally or transversely, by means of the handles shown in the drawing. These motions are made automatic by connection, through gearing, with the feed-screw. An automatic longitudinal motion is given to the base of the slide-rest by means of the feeding-shaft and worm, while it is moved by hand in the same direction—when thrown "out of gear" with the feeding-shaft—by means of a pinion gearing into the "rack."

The "leading-screw," which in the plate is contained between the cheeks of the bed, and consequently only shown where it gears in rear with the pinion-wheel, gives the required longitudinal motion to the side-rest in screw-cutting. A series of change-wheels is provided with each lathe, by a suitable combination of which any desired pitch can be given to the thread cut. The back-center can be adjusted by hand to any position, and in many machines an automatic longitudinal motion is provided by means of gearing in rear, to enable it to carry a boring-rod.

Figs. 1 and 2, Plate XXII, represent a usual form of rough and fine cutters; Figs. 3 and 4, rough and fine boring-tools. The principal distinction between tools for rough and fine work consists in the fact that the former are narrow and deep on the cutting edge, while the latter are broad and shallow.

Tools used for boring large masses of metal are generally set in a head composed of hard wood, as represented in drawings. Apple wood is much used for this purpose.

Fig. 5 represents in cross-sections such a boring-head in which the cutting-tool is adjustable. In the heads represented in Figs. 3 and 4 the tool when worn down must be taken out and reset.

In boring short tubes, such as the sections of the A tube, the cutter is generally passed through a slot in the boring-bar, which passes, in an ordinary lathe, from the "head-stock" to the "back-center." The tube is then attached to a saddle which has a motion of translation, while the cutter has the motion of rotation received from the "head-stock." Ordinarily, both in boring and turning, the cutter has the motion of translation, while the tube revolves.

In boring or turning cast iron, it is not usual to use a lubricant. In turning wrought iron, a mixture of soap and water is allowed to drip upon the tool, which serves to diminish the friction on the tool and preserves its temper.

In boring wrought iron, no lubricant need be used for the rough-cut, but oil must be used during the finishing cut. Previous to the first turning of any article, the axis must be found so as to center it truly in the lathe. This is simply done in a solid cylinder by finding centers at each end with a pair of compasses; but in the case of a tube a mandrel must be inserted in each end in order that the axis may be actually obtained.

After the casing has been bored out to receive the tube, careful measurements are made with the star-gauge for every inch of length of bore. These measurements, plotted on paper, are the workman's guide in so finishing the tube that the play between it and the casing shall not exceed that prescribed.

Before shrinking the reinforcing tube upon the tube proper, both are subjected to the hydraulic test. The apparatus for applying this test

is illustrated on Plate XXI. It consists of two iron cross-heads fitted to the ends of the tube, and which are enabled to sustain the pressure applied through the medium of the connecting rods. Leather washers are used to render the cross-heads water-proof. The water is forced in by a steam-pump through one of the cross-heads, and the degree of pressure—which must reach 120 pounds to the square inch—is registered by the gauge.

The reinforcing tube is now shrunk on, and the united tubes returned to the bed and finished, and then inserted in the casing. The muzzle-collar is then screwed into place, and the steel "securing-pin" inserted through the casing.

RIFLING.

It is usual to rifle the tube before it is inserted in the casing; but as it is not infrequently done at this stage of the work, the description of it is here introduced.

Only a single groove is cut at a time, and that, ordinarily, as the cutter is going down the bore. All the grooves in a gun are first cut out roughly and then finished with another cutter. The distance between the grooves is regulated by a disk fixed to the breech of the gun, having its periphery equally divided by as many notches as there are to be grooves. The gun is fixed each time by a pawl, and, when a new groove has to be cut, is turned round to the next notch. Sometimes the periphery is simply subdivided into the required number of equal spaces, while a stationary pointer indicates the position to which the marks on the disk are to be successively brought.

The gun is held horizontally in its bed in front of the machine, and remains stationary while the head carrying the cutter moves in and out the bore. Consequently it is necessary to make the bar, to which the head is attached, turn as it advances and returns.

Three varieties of machines used in this country for rifling guns are shown in Plates XXIV and XXV. They differ from each other in the mechanism employed to give this motion of rotation to the cutter. In all of them, the gun-metal head, which carries the cutter, fits the bore accurately by means of burnishers. It is fastened to a stout, hollow iron bar, termed the "rifling-bar." This bar is fixed to a saddle which can be moved backwards and forwards, but is capable of a motion of rotation independent of it.

Plate XXV represents a machine in which this motion is acquired through the agency of a "copying-bar." A small pinion attached to the rear of the rifling-bar, Fig. 3, gears into a rack sliding in the saddle at right angles to the bar itself. The outer end of the rack is fitted with three small rollers, or friction wheels, which run along a copying-bar fixed to one side of the rifling-machine. This copying-bar is inclined to the rifling-bar at an angle which depends upon the twist required. The greater the angle, the more the rack will be pulled out by the rollers as the saddle, to which it is attached, advances, and the greater will be the pitch of the groove cut.

For a "uniform twist," the straight bar is used, and can, of course, be adapted for any gun.

For an "increasing twist," the copying-bar assumes the shape of a curve of a parabola.

Figs. 2, 3, 4, and 5 (Plate XXIII) represent a rifling-machine, formerly much used, but now almost discarded, in which the rotation to the cutter is secured by the bearing of a plate, fixed near the muzzle of the gun along a groove cut in the rifling-bar itself. Each bar is provided

with several different grooves, and can be used, consequently, for as many different guns. The objection to this machine is found in the insufficient steadiness afforded by the plate when the cutter has advanced towards the bottom of the bore; consequently, when used at all, it is restricted to the case of small, short guns.

Plate XXIV, Fig. 1, represents a rear view of a machine, in which the rotary motion is given to the rifling-bar simply by gearing. As the bed slides backwards and forwards, the small pinion on the right runs in a rack alongside, and imparts the consequent motion through the worm to the pinion or worm-wheel attached to the rifling-bar.

By altering the relative sizes of the pinion-wheels, any desired pitch can be obtained.

Figs. 2 and 3 represent the same machine arranged for cutting grooves with increasing twist. The motion of the bed is transferred as before, by means of a rack and pinion, and worm, to a worm-wheel working in a short rack placed at right angles to the rifling-bar. An arm is hinged to the inner end of the rack, and also to a projection on the rifling-bar; consequently, as the bed moves forward and backward, the rack will move in and out, and the motion of the rifling-bar be correspondingly controlled. When the cutter enters the bore, the rack is at its outer limit; but as it moves down the bore, the rack slides uniformly inwards, and the rate of rotation of the rifling-bar uniformly decreases as the connecting arm approaches the vertical position.

All these machines are provided with some one of the various arrangements for securing the "return motion."

Fig. 3 shows the arrangement of the cutter and cutter-head, and a somewhat unusual method of securing the muzzle of the gun in the bed. With heavy guns, the muzzle, ordinarily, simply rests in an adjustable saddle, its weight being sufficient to keep it steady. Along the under side of the rifling-bar is a rod, which slides in a groove. The front end of the rod is wedge-shaped, and on the other end of the rod, near the rear of the rifling-bar, is an arm which serves as a handle. The cutter-head attached to the bar contains the tool and its holder, with space enough in front of them to catch and contain the chips of metal taken from the bore. The cutter is forced out when the handle of the rod is moved forward, and returns within the cutter-head when the handle is moved back. Near the handle of the rod is a bolt, which is attached to the rifling-bar. The distance between the end of the bolt and the projecting arm or handle, determines the extent to which the cutter can be pushed out. The nut on the bolt is fixed, before commencing work, at its proper position to give the required depth to the grooves. Several cuts are required (both in roughing and finishing), for each groove, and each successive position of the cutter is secured by slightly unscrewing the bolt before each cut. In the drawing, the bolt is adjusted for the last or deepest cut.

A piece of scantling (Fig. 3) is attached near the muzzle of the gun, and projecting beyond it, and of such length and in such position that it will strike and push back the arm of the rod when the cutter has reached the end of the groove. The motion of the machine is then reversed, and when it starts again after its return one workman shoves the handle forward again, while another adjusts the bolt. No lubricant is used while rifling.

In the 8-inch converted rifle, the grooves commence at a distance of 10 inches from the bottom of bore.

LAPPING.

During rifling the metal on the edges of the grooves occasionally becomes "burred." The bore must therefore be smoothed, and this is accomplished by a process called "lapping." The operation consists in working backward and forward in the bore a wooden head covered with lead and smeared over with emery powder and oil. The bore of the gun-casing is also subjected to the same operation before the insertion of the tube.

Both the tube and collar now project beyond the muzzle of the casing. They are therefore cut off flush with it, and finished as shown in Plate XXX.

The hole is tapped for the vent-bushing, which is then screwed into place, and its lower end finished off flush with the surface of the bore.

The gun is now ready for final inspection and powder proof.

INSPECTION.

Instruments.

1. *Star gauge.*—This is an instrument for measuring the diameter of the bore of a gun at any part. The head (Plate XXIX, Fig. 2) is made of brass, with four steel sockets for the measuring points used in gauging smooth-bore guns or tubes, two of the sockets being soldered fast into the head and the other two movable. The two stationary points act simply as guides, and are held horizontally in the bore, while the movable or measuring points are held and act vertically.

In front of this set are three movable sockets, used when gauging rifled guns. These are capable of a lateral motion, to enable them to be adjusted for use with guns of any size or any number of grooves. The staff, to which the head is permanently attached, is a hollow brass tube, made in three or more sections, and graduated for its entire length into inches and quarters, commencing at the measuring points (smooth-bore), so as to indicate the distance of the latter from the muzzle of the gun. Through the staff runs a square steel rod, divided into the same number of sections as the staff, and which are arranged with threads, so as to be screwed together.

The movable sockets and points are pushed out by means of a conical slider attached to the front end of the rod. This slider tapers 0.35 of an inch in a length of 22 inches, so that by pushing the slider the 35th part of this length (about 0.06 inch) the distance between the movable points is increased 0.01 inch.

The handle* (Fig. 1) is also a brass tube, and is secured on to the rear of the square rod. It has a sliding motion along the end of the staff to which it is fitted. Toward the front part is a slit, on the side of which is marked a scale to indicate the movements of the measuring points. Each joint of the staff carries a mark made on a small silver plate, which shows through the slit the zero point on the scale, when

* (Fig. 1) *a b*, handle, which controls the measuring points; *a c*, front part of handle, which carries the scale; *d e*, rear part of handle, which moves on front part and serves for adjusting the instrument; *a*, cap, by which handle is attached to square bar; *g* is a tube, embracing the cap at one end, and held to it by a projecting ring (*h h*) working in an annular groove; at the other end it is attached by a left-handed screw to the adjusting tube K, which at its other end is joined by a right-handed screw to the front part of the handle; *f*, clamp-screw, which fastens together the front and rear of handle; *m*, rear end of last section of staff, with screw-thread, to which, if desired, another section may be fitted.

the measuring points are adjusted to the true diameter of the bore. For purposes of adjustment the rear half of the handle can be moved by screwing backward or forward along the front half, and can be secured, when desired, by a clamp-screw.

A ring-gauge—being a simple steel ring of sufficient thickness to insure stiffness—is used for each caliber in connection with and for adjusting the gauge. Each ring-gauge is accompanied by a set of measuring points, which are screwed into the sockets by an ordinary wrench. A rest in the form of a T (Figs. 2 and 3) is placed in the mouth of the gun to support the instrument in the axis of the bore. The upright branch is movable for convenience in packing, and each carries a slide which can be adjusted for different sizes of bore. To facilitate the adjustment of the rest, the positions of the slides on the different branches are permanently marked for different calibers of guns.

Fig. 4 represents a "guide" used in gauging a rifled gun, to make the measuring points follow the lands as they proceed along the bore.

The hexagonal hole in the center is fitted on to that portion of the end of one of the measuring points, which is similarly shaped. Two little arms on either side of the guide-piece face each other, and can be moved toward or from each other by means of sliding plates to which they are attached. For this adjustment finely divided scales are marked on the sliding plates. When in the bore the two arms rest in two contiguous grooves, and embrace between them the land which the measuring point is forced to follow.

To prevent obstructing the motion of the measuring point when it is shoved out by the conical slider, the arms rest upon light springs, which are simply compressed during the movement.

The hexagonal socket is made to turn within the rest of the guide-piece, to allow the necessary freedom to the arms.

To adjust the instrument, the ring-gauge of the required diameter is so held as to surround the corresponding points which have been fitted to the sockets. The points are then pushed out by the handle till in contact with the ring; and if the zero points do not coincide, the clamp-screw is loosened and the rear part of the handle screwed backwards or forwards till the coincidence is effected. The clamp-screw is then tightened and the instrument is ready for use.

Before and after every set of measurements the adjustment of the instrument must be similarly verified. Where more than two lengths are used, the staff must be supported when taking measurements near the muzzle of the gun. The star-gauge, its points and rest, are packed in one box, and the ring-gauges in another.

2. *Calipers* for measuring exterior diameters (Plate XXVIII, Fig. 1).—This instrument was designed especially for use in connection with the construction of tubes for 8-inch converted rifles. It consists of a curved steel plate and two attached measuring points movable along the same right line. One of these points is fastened to a rod which slides in a socket attached to the steel plate. The rod is designed to occupy one of two positions, according to the size of the diameters to be measured, and is secured in either of these positions by a clamp-screw. At the other end of the curved plate the second measuring point terminates a graduated limb, which, by means of a vernier and sliding microscope, can be read to 0.001-inch. This limb is fitted with a clamp and slow-motion screw, and has two sets of graduations, the one above the other; the lower read from about 9 inches to 14 inches, and the upper from about 12 inches to 17 inches. The lower graduations are used when the

rod opposite is pushed in and clamped at its inner limit; the upper graduations, when the rod is pulled out and clamped at its outer limit.

Figs. 2 and 3 represent steel bars 14 inches and 10 inches long, respectively, which are used in adjusting the calipers. The distance between the measuring points should be the same as the lengths of the respective bars, in the positions when the rod is entirely drawn out and when the rod is entirely pushed in. Should the zero points of the vernier and scale not coincide when either bar is tried between the points, that point attached to the rod can be screwed in or out, as necessary, by the pin shown in Fig. 4.

In making nice measurements, it is indispensable that the plane of the instrument be kept at right angles to the axis of the tube. This is secured by a wooden guide (Fig. 1), which is held in rear of the instrument and is slid along the tube from one position to another. The base of the guide has the same curvature as the exterior of the tube, and is held firmly upright by two projecting arms extending in rear from either side, and which rest on the surface of the tube. By keeping the curved plate of the calipers in contact with the face of the guide, its true position is secured.

3. *Standard scale* (Fig. 5), arranged for measuring both exterior and interior diameter.—All other instruments are verified by this, and any variation from it is accepted as an error, for which correction must be made either in the instrument or the record. The points and other gauges used by the workman are measured by the standard scale when new, and verified from time to time during the progress of the work.

4. *A graduated wooden staff* to measure the length of the bore.—This is terminated at the bottom with an iron measuring point, and is fitted near either end with wooden supports shaped like a half tompion, which serves to hold the staff in the axis when inserted in the bore.

5. *A wooden rule* for measuring exterior lengths.

6. *A wooden profile* to verify the position of the exterior orifice of the vent.

7. The *vent gauges* are two pointed pieces of steel wire 0.005 inch greater and less than the true diameter of the vent.

8. The *vent searcher* is a hooked steel wire about half the diameter of the vent.

9. A *rammer-head*, shaped to the form of the bottom of the bore, and furnished with a staff, is used to ascertain the interior position of the vent.

10. *Steel templet* for verifying size and shape of breech-cup, base of tube, all shoulders, dimensions of screw-threads, and face of gun.

11. A *mirror; sperm candles; beeswax; rubber.*

12. *Rammer; sponge* and *priming-wire;* and *wedges* for taking impressions.

13. *Hammer;* and *figure* and *letter stamps*, to affix the required marks.

INSPECTION.

The duties of the inspection commence with the inception of the work, and the most important are performed before the gun is completed.

The breech-cup is verified by the steel templet before it is screwed into place. The different shoulders and the shape and pitch of screw-threads are similarly gauged before the parts are united; diameters of tubes are verified, and the base of the tube and recess for muzzle-collar before the insertion. The dimensions of the casing are also proven.

When the gun is presented for final inspection it is placed horizontally on skids.

The *interior of the bore is first examined* by reflecting the sun's rays into it from the mirror; or, if the sun be obscured, by a lighted candle placed on the end of a rod and inserted into the bore.

The bore of the piece is then measured with the star-gauge. Beginning at the bottom, measurements should be made at intervals of one-quarter inch to the front of seat of shot, and at intervals of one inch from that point to the muzzle. In rifled guns the measurements are taken from land to land, and afterwards from groove to groove, the head of the star-gauge being fitted with a suitable "guide" to insure the proper position of the measuring points.

To ascertain the *length of bore*, shove the graduated staff into the bore until the metal point touches the bottom. Apply a straight-edge to the face of the muzzle, and read the length of bore on the staff.

The position of the *exterior orifice of the vent* is verified by the wooden profile, which is applied longitudinally along the base; the position of the *steadying-pin* by the wooden rule. The position of the *interior orifice of the vent* is found from the marks made on the rammer-head by the vent-gauge pushed through the vent while the rammer-head is held against the bottom of the bore.

The diameter of the vent is verified by the gauges.

The *width of the lands and grooves* is also verified by gauges, and an impression is taken, in wax or gutta-percha, of the interior orifice of the vent, to see that it is finished flush with the surface of the bore.

The face of the piece is then gauged by its templet; the gun weighed, and preponderance determined.

MARKS.

Converted guns are marked as follows: The *number of the gun;* the *weight of the piece in pounds;* the *initials of the inspector's name*, and that of the *foundry where the gun is converted* and the *year of the conversion* on the face of the tube, in a circle concentric with the bore, in letters and figures at least one inch long. The initials of the *foundry where the tube is made*, and the *number of the tube*, in small type, on the face of the tube, under the initials of the inspector.

The results of all final measurements and examinations are noted on the inspection report of the gun.

8-INCH CONVERTED RIFLES, MUZZLE-INSERTION (PALLISER).

PARTS.

1. The gun-casing bored out to receive the tube.
2. The rifled coiled wrought-iron A tube closed at the breech by a wrought-iron cap.
3. the reinforcing B tube.
4. The muzzle-collar.
5. The securing-pin.
6. The spiral gas-escape, which runs round that portion of the A tube where turned down for the B tube, and connects with a small gas-channel through the casing.

THE CASING.

The gun is placed in the bed, and accurately bored to 13.5 inches; the recess and screw-thread for muzzle-collar cut, and the gas-channel, or indicator hole, bored through the breech.

THE COILED WROUGHT-IRON TUBES.

The bar-iron for the A tubes, as received at the foundry, is in lengths of 18 and 16¼ feet, with the hexagonal cross-section previously described; the iron for the B tubes is received in lengths of 28 feet, the cross-section being a square of 2⅝ inches on a side.

The weights are about as follows:

	Pounds.
Long bar for A tube	749
Short bar for A tube	678
Bar for B tube	608

The A tube is made, as previously described, in four sections, or short tubes welded together. The B tube, like the sections of the A tube, is formed from two bars, which are united, end to end, before coiling. The long bars for the A tube are employed in the breech section, in order to give that section such length that the joint between it and the next section shall be well in advance of the B tube.

Transferred to the finishing-shop, the B tube is bored out to 10 inches and rough-turned to 13.75 inches; the A tube is rough-turned to the same diameter and rough-bored to a little less than 8 inches; turned down for the muzzle-collar and for the B tube (allowing 0.003 inch shrinkage), and the screw-thread cut for the breech-cup.

The breech-cup is then screwed into place and the spiral gas-escape cut upon the A tube.

Both tubes are now subjected to the hydraulic test.

The B tube is now shrunk upon the A tube. This operation is conducted as follows:

The B tube is stood vertically, breech down, over a wood fire, and surrounded by an open cylinder of sheet-iron. The A tube is suspended, breech down, from a crane near by. When sufficiently expanded by heat, the B tube is placed upright on an iron platform, under the A tube, which is then lowered into place, the weight of the A tube forcing the B tube well "home" to the shoulder upon the former. A small stream of water is then thrown upon the exterior near the shoulder (the rest of the tube is partially protected from the water) to cool the B tube in that vicinity first, and thus prevent the open joint which is apt to occur from the longitudinal contraction of the B tube in cooling.*

The tube is then returned to the lathe and turned to fit the casing, allowing a play of 0.007 inch between its diameter and that of the casing for a distance of 32.75 inches from the bottom, and of 0.015 inch for the remainder of its length.

The tube being now ready for insertion, it is oiled and then wiped, and the breech smeared with red lead. It is then lifted by a crane, swung round in front of the muzzle of the casing, and inserted as far as the slings will permit. The slings are then removed and a block and tackle attached to the muzzle, by means of which the tube is forced home. The tube is then withdrawn, and the breech end examined to ascertain that it has an even bearing upon the bottom of the bore of the casing, and also that the curved portion of the bottom of the tube is not in contact with the corresponding curved portion of the casing, a difference of 0.005 inch between their radii being here required to prevent the tube from acting as a wedge, with the tendency to split open the cast-iron casing.

*As a point of fact, this joint always proves more or less open (rarely exceeding, however, 0.02 inch or 0.03 inch), and is subsequently closed on the exterior while being finished, by crowding into it with the hammer, the metal of a small lip left on the B tube while being turned.

These important points having been satisfactorily established, the tube is wiped and again inserted and forced "home."

The muzzle-collar is then screwed into place, and the steel securing-pin inserted through the casing.

TABLE II.

Dimensions and variations allowed for 8-inch rifles, converted (muzzle-insertion).

Subject of measurement.	Dimensions.		Variations.	
	Prescribed.	Actual.	Allowed.	Actual.
	Inches.		*Inches.*	
Total length of tube	120	....	± .2	
Total length of bore of casing	120	....		
Maximum eccentricity of bore of casing	.002	....	0	....
Length of B tube	32.75	....	±0.1	....
Interior diameter of B tube	10.00	....	0	....
Diameter of A tube underneath B tube	10.003	....		
Shrinkage	0.003	....	0	....
Depth of gas-escape on A tube	0.05	....	± .01	....
Width of gas-escape on A tube	0.10	....	0	....
Pitch of spiral of gas-escape	7.3	....	0	....
Depth of wrought-iron cup at bottom of tube	2.75	....	± .05	....
Thickness at bottom of wrought-iron cup	2.75	....	± .05	....
Diameter of cup over threads	7.8	....	.01	....
Pitch of thread on cup	0.3	....	0	....
Diameter of interior of cup, at top	7.00	....	.01	....
Diameter of interior of cup, at bottom	4.6	....	.01	....
Diameter of finished tube, from bottom to 32 inches	13.493	....	± .1	....
Diameter of bore of casing, from bottom to 32 inches	13.500	....		....
Corresponding play	.007	....	+0	....
Diameter of finished tube, from 32 inches, from bottom to muzzle	13.485	....	±0.1	....
Diameter of bore of casing, from 32 inches, from bottom to muzzle	13.500	....		
Corresponding play	.015	....	0	....
Length of neck of tube under muzzle-collar	3.75	....	±0.1	....
Length of muzzle-collar	3.75	....		
Length of recess in casing	4.4	....	± .2	....
Length of screw on muzzle-collar	2.90	....	±0.1	
Length of screw on recess in casing	2.775	....		
Excess in length of screw on collar over that on recess	.125	....	.02	....
Diameter of tube over neck	12.00	....	±0.3	....
Interior diameter of muzzle-collar	12.01	....		
Corresponding play	.01	....	0	....
Diameter of muzzle-collar across threads	13.80	....	± .03	....
Diameter of recess on casing	13.81	....		
Play between collar and casing	.01	....	0	....
Thickness of collar	0.9	....	± .01	....
Pitch of thread on collar	0.3	....	0	....
Radius of curve at bottom of bore of casing	1.75	....	± .01	....
Radius of curve at bottom of tube	1.80	....		
Diameter of gas-channel through casing	0.2	....	± .02	....
Distance of interior orifice below axis of bore	5.00	....	± .2	....
Distance of exterior orifice from tangent to bottom of gun	9.9	....	± .2	....
Length of bore of A tube	117.25	....	± .02	....
Length of rifled portion of bore	107.25	....	± .25	....
Diameter of bore across lands	8.00	....	0	....
Width of grooves	.83776	....	± .01	....
Width of lands	.83776	....	± .01	....
Depth of grooves	.075	....	.005	....
Pitch of rifling	40 feet	....	0	....
Diameter of vent	0.2	....	± .005	....
Diameter of vent-bushing	1.00	....	± .01	....
Axis of vent from bottom of bore	3.50	....	± .2	....
Axis of vent from vertical plane through axis of bore	2.50	....	± .05	....
Length of securing-pin	5.25	....	± .02	....
Diameter of securing-pin	1.50	....	.005	....
Distance of securing-pin from muzzle	60	....	0.2	....

PROOF.—Two rounds, with battering charges and full weight projectiles, are fired for proof of converted rifles.

8-INCH CONVERTED RIFLES, BREECH-INSERTION (PRESENT SYSTEM).

PARTS.

1. The gun casing, A (Plate XXX), bored out to receive the tube.
2. The rifled, coiled wrought-iron tube, B.
3. The jacket, C.
4. The breech-plug, D.
5. The muzzle-collar, E.
6. The breech-cup.
7. The securing-pin.

THE CASING.

The gun is placed in the "bed," and a "piercer," introduced at the muzzle, runs from the bottom of the bore through the breech.

The opening thus obtained is gradually enlarged till it reaches the size of the bore (10 inches), and the entire length of the gun is then bored to a diameter of 10.5 inches. After the "recess" and screw-thread for the muzzle-collar have been cut, the gun is reversed in the bed, and rough and fine bored successively as follows:

For a distance, from the tangent at the base, of 68.16 inches, to 11.5 inches; for distances, from the same tangent, of 59.66 and 22.24 inches, to diameters of 13.5 and 14.7 inches, respectively. These distances include the lengths of the uniting surfaces.

A screw-thread is now cut in the breech end of the casing, the depth of which is 0.4 inch; the width, 0.1 inch; and the pitch, 2.54 inches.

The casing is then carefully measured with the star-gauge for every inch of length along both horizontal and vertical diameters, and the results plotted and marked on paper. A very carefully made wooden profile is also fitted in the bore for its entire length, and a metallic templet accurately adjusted to the threads of the screws.

The bar-iron is received at the foundry in the following sizes and lengths:

For tubes, 2.25 inches square, 27 feet long; weight, 450 pounds.

For jackets, 2.25 inches square, 18 feet long; weight, 306 pounds.

For jackets, 4 by 3.35 inches (hexagonal), 20 feet long; weight, 811 pounds.

The ends which are cut from the bars at the rolling-mill are used in the construction of the section which finds place at the rear of the jacket.

The *tube* is made in four sections and the jacket in three, all the sections of the tube and the two forward ones of the jacket being formed from two bars which are united end to end before coiling.

When prepared for welding, the rear section for the jacket is about 32 inches long, bored to 6 inches, and with an exterior diameter of about 16.25 inches; the middle section (made of iron 4 by 3.35 inches) is about 31 inches long with the same exterior and interior diameters for one-half its length, and for the remainder an exterior diameter of about 15 inches and an interior diameter of 9.5 inches; the front section (made of 2.25 inches square iron) about 32 inches long with the smaller exterior and interior diameters of the middle section.

After welding one middle section to an end of the rear section, another is welded to the free end of the first-mentioned section. The three sections thus united are placed in the lathe and a cut taken midway between the joints; and to each of the two short tubes thus formed a front section is subsequently welded.

The jacket is then cut to a length of about 60 inches, in such manner as to throw the joint between the rear section and coiled section, at a distance of 49.25 inches from the front of the jacket. It is then bored for a length of 43 inches from the front to a diameter of 10.5 inches, the screw-thread to receive the cast-iron breech-plug cut in the rear part, and rough turned for its entire length.

After the tube has been turned down for the jacket, and for the rest of its length rough turned, both tube and jacket are proved with water —120 pounds to the square inch.

The jacket is finished about $\frac{3}{16}$-inch shorter than the corresponding length of the tube, to insure contact between the base of the tube and the shoulder of the jacket when the two are united by shrinking.

To prevent the jacket from turning upon the tube during the operation of screwing the two into the casing, two dowels are screwed into the base of the tube, the projecting ends of which are designed to fit into corresponding recesses in the shoulder of the jacket. To insure this fit, which must be accomplished during the operation of shrinking (of short duration), the screw-threads for the dowels in the base of the tube are tapped through holes in a steel templet, which is so shaped on its two faces as to fit the base of the tube and the face of the shoulder of the jacket.

The recesses in the jacket are bored through the same holes in the same templet, and the necessary accuracy consequently assured.

The jacket is then shrunk on the tube. The united tube is then accurately turned as far as that point on the jacket where the screw-thread commences, to the dimensions of the bore of the casing, into which it is afterwards gradually fitted, slight corrections where necessary being made with the file. A wooden profile, fitted accurately to that which had been adjusted to the bore of the casing, is used to assist in fixing the shoulders and connecting surfaces on the tube. The thread is then cut upon the rear part of the jacket. A steel templet, the reciprocal of that which had been fitted to the thread in the casing, is used, in connection with the calipers, to gauge the thread.

The cast-iron breech-plug is cast from the air-furnace, turned, and its screw-thread cut. The rear end of it, being square, supplies a point of application for the lever in screwing the tube into place.

To enable the tube to be withdrawn while fitting it into place, the breech-plug is secured to the rear face of the jacket by a steel pin.

The shoulders are now smeared with red lead, and the tube is first inserted by blocks and tackle, and finally screwed "home." The power is applied by means of a heavy iron lever, which is worked by a crane. The tube is then withdrawn to examine the contact of the shoulders; after this has been made satisfactory, the tube is finally inserted.

The muzzle-collar and securing-pin are then screwed into place, and the cast-iron breech-plug finished.

CONSTRUCTION REPORT OF AN 8-INCH MUZZLE-LOADING RIFLE CONVERTED FROM A 10-INCH RODMAN SMOOTH-BORE BY LINING, BY BREECH-INSERTION, WITH A COILED WROUGHT-IRON TUBE, HAVING A JACKET SHRUNK ON, EXTENDING THROUGH THE BREECH.

PRELIMINARY REMARKS.

(Plate XXX.)

The difficulties of securing perfect weldings in coiled wrought-iron tubes have led in some instances, in the history of the employment of linings constructed in the manner and on the present plan of muzzle-insertion, to the development of grave accidents in service, tubes being blown out and the muzzles torn off, all from defective welds.

The most satisfactory and secure remedy for this imperfection undoubtedly lies in the provision of a shoulder on the tube (in front of the charge), the gun being recessed for its reception.

An otherwise strong and durable construction, embodying this feature, must accordingly have an important advantage over the present plan of muzzle-insertion, in which no adequate provision can be made to prevent the destructive effects of a tube being blown out. This accident is likely to occur if all the welds are not sound—a perfection which it is impossible, from the nature of the construction of coiled wrought-iron tubes, to uniformly and certainly attain.

The uniform success of our present guns is, in a measure, due to excellence of work and care in manufacture; but it is evident that a decided improvement attains, if we can have perfect immunity from the defect alluded to above, while securing a perfectly reliable construction in other respects.

A consideration of the question has led to the construction of a gun on an improved plan of breech-insertion, having, it is believed, more durability than the present plan of muzzle-insertion, and securing the other advantages above quoted.

The imperfections of breech-insertion, in alterations heretofore made, have arisen from the mode of construction employed, to wit, separating the breech-plug from the strengthening tube shrunk on the inner tube or lining; also from the solid construction of the plug.

The throwing of the entire longitudinal strain on to a breech-plug by depriving it of all assistance from the longitudinal strength of the enveloping jacket, produces a line of longitudinal weakness at the junction of the tube and plug, where the longitudinal and tangential strains, under fire, combine to produce rupture. This fact is well established by experiments in England.

In the construction under consideration, the jacket is shrunk on the tube, and extends continuously with a uniform thickness from a point a short distance in front of the trunnions to the breech-cup of the inner tube, and thence, with an increased thickness, clear through the breech to its face.

This unbroken continuity, and the yielding, hollow, wrought-iron breech thus formed, give all the strength desirable at the bottom of the bore to resist the combined longitudinal and tangential strains at that point; and the breech portion of the jacket, by its hollow form being permitted to expand in unison with the tube when the latter is distended under the strains of discharge, avoids the danger of rupture liable to result from the rigidity of a solid, unyielding breech. A square cut plus thread

cut on the breech portion of the jacket corresponds with a minus thread cut on the cast iron, each to form the union of one with the other. The area of cross-section of the wrought iron is such as to have its strength proportional to the strength of the thread on the cast iron, reference being had to the relative strength of the two metals.

The breech portion of the jacket, it will be observed, is so constructed as to overlap the bottom of the tube and the exterior portion of its cup. The longitudinal thrust consequently is, at this point, principally borne by the wrought-iron jacket, and not by the secondary breech-plug, simply used to close the hollow part of the former. By these arrangements, the greatest resistance is secured to longitudinal strains.

A breech-plug of cast iron completes the construction of the breech. The inner tube, *shouldered* and closed at the bottom in the usual manner, completes the mention of the general features of the construction.

It will be seen that the jacket (1″.5 thick) extends to the front a distance of about 40 inches from the bottom of the bore, thus reinforcing the inner tube (1″.25 thick) to a greater length than in the case of the B tubes of the present constructions, and consequently fully strengthening it over all the space where the pressures are at all dangerous.

DESCRIPTION OF THE GUN.

Plate XXX represents a 10-inch Rodman smooth-bore gun, with its lining inserted from the breech.

The gun is essentially composed of three parts: (A) the original 10-inch smooth-bore, bored out to receive the lining; (B) a lining tube of coiled wrought iron (welded), with a jacket (C) of wrought iron with its hollow base or plug extending to the face of the breech; and the breech-plug (D). The bottom of the tube is closed by a wrought-iron base or cup (F). A shoulder, on the inner tube, prevents the tube from being thrust forward by the effects of repeated firings, or blown out from imperfect coil-welds. A screw collar, E, at the muzzle, gives additional security, resisting any forward thrust of the metal of the tube in front of the shoulders. The dimensions of the finished bore of the cast-iron body, and the exterior dimensions of the wrought-iron tube, are given in Table No. 1.

It will be seen that the play between the cast-iron body and tube and jacket does not exceed 0.01 inch for a length of 88 inches from the muzzle; nor 0.004 inch from this point to the commencement of the screw-thread.

The greatest diameter of the tube and jacket is 14.7 inches. The diameter of the tube from the muzzle-collar to the first shoulder is 10.5 inches. The maximum thickness of the tube and jacket is, therefore, 3.35 inches and the minimum thickness of the tube is 1.25 inches.

RIFLING.

The rifling of the gun consists of 15 lands and grooves, each of equal width.

Width of lands and grooves	0.8377 inch.
Depth of grooves	0.075 inch.

Twist uniform, one turn in 40 feet.

The rifling stops at a point 10 inches from the bottom of the bore, and the diameter of the unrifled portion of the bore is equal to that of the rifled portion across lands.

VENTING.

The old vent was closed (the copper bushing having been removed) by a wrought-iron screw-plug, and 2.75 inches nearer the muzzle a new one was bored, parallel to the vertical plane through the axis of the bore, and distant therefrom 2.50 inches. The axis of the vent enters the bore at 3.5 inches from the bottom.

FABRICATION OF THE GUN.

The tube was manufactured and work of conversion performed at the West Point foundry.

The gun selected for the conversion was 10-inch Rodman gun No. 16, manufactured at the South Boston foundry, and inspected and proved in 1865.

The mechanical tests of the metal employed gave the following results:

Density	7.223
Tenacity, pounds, per square inch	31,315

The tube was made of 2.25 inch coiled Ulster tube-iron; the jacket of coiled Ulster tube-iron 4 by 3.35 inches, and its rear section of a forging from scrap of the same iron; the breech-plug of gun metal.

The following results were obtained by mechanical tests of the iron used. The specimens of the bar iron were taken from the bar and with the fiber:

Specimens.	Area of cross-section.	Density.	Tenacity.	Elongation per inch at rupture.
	Inches.		*Pounds.*	*Inches.*
1. From 2.25 inches bar } Tube	0.19635	....	51,925	0.280
2. From 2.25 inches bar } Tube	0.19635	....	46,855	0.2525
3. From 4 by 3.35 inches bar } Coiled sections of jacket	0.1963	....	46,855	0.300
4. From 4 by 3.35 inches bar } Coiled sections of jacket	0.1971	....	48,698	0.3168
5. Taken from solid forging, rear section of jacket	0.19635	....	49,402	0.2626
6. Taken from casting, breech-plug	1.112	7.3426	29,221	....

The tube was made in the usual manner in four sections. The jacket was made in three sections, the rear one from the solid forging. When prepared for welding, the rear section was 22.5 inches long, and bored to 6 inches; the middle section was 31 inches long, and bored for one-half its length to 6 inches; for the other (the front) half to 9.5 inches; the front section was 32 inches long and bored to 9.5 inches. After welding, the jacket was cut to a length of about 60 inches, in such manner as to throw the joint between the forged and coiled sections at a distance of 49.25 inches from the front of the jacket.

After the tube had been bored out, fitted with a breech-cup, and turned down to receive the jacket, and the latter bored to a diameter about 0.005 inch less than the corresponding diameter of the tube and rough turned to a diameter slightly in excess of its greatest finished dimensions, both were proved with water (120 pounds to the square inch). The jacket was left about $\frac{3}{16}$-inch shorter than the tube where turned down to receive it, to insure contact between the base of the tube and the corresponding shoulder of the jacket when united by shrinking.

To prevent the jacket from turning upon the tube during the operation of screwing the two into the threads prepared for them in the casing, two dowels were screwed into the base of the tube, which were designed to fit into corresponding recesses in the shoulder of the jacket. To insure this fit, which must be accomplished during the operation of shrinking, the screw-threads for the dowels in the base of the tube were tapped through holes in a steel templet, which was so shaped on its two faces as to fit the base of the tube and the face of the shoulder of the jacket. The recesses in the jacket were then bored through the same holes in the same templet.

The jacket was then shrunk onto the tube, and, after cooling, the forward joint between the two was found to be closed to within 0.03 inch. The joint was subsequently closed on the exterior by crowding into it metal from a lip left for the purpose on the tube.

The exterior of the tube and jacket was then turned to diameters as nearly approaching those of the larger and smaller portions of the cast-iron body as was compatible with their insertion by mechanical means, and a screw-thread was cut upon the base of the jacket to correspond to that cut in the breech of the casing.

The tube and jacket, as a whole, were then inserted, forced down in the casing, and screwed home into position by means of levers, after which the muzzle-collar was screwed in and the steel pin inserted.

INSPECTION.

Careful inspection was made of every detail incident to the construction, and the gun, after completion, finally inspected, accepted as satisfactory, and shipped to Sandy Hook for powder proof.

Principal dimensions.

Length of bore	inches	117.25
Length of tube	do	120
Length of jacket over tube	do	43
Total length of finished tube	do	136.66
Interior diameter of jacket	do	10.50
Exterior diameter of tube under jacket	do	10.507
Diameter of finished tube from screw thread to first shoulder	do	14.712
Corresponding diameter of bore of casing	do	14.714
Diameter of finished tube from first shoulder to second shoulder	do	13.494
Corresponding diameter of bore of casing	do	13.498
Diameter of finished tube from second shoulder to third shoulder	do	11.489
Corresponding diameter of bore of casing	do	11.494
Diameter of finished tube from third shoulder to neck	do	10.489
Corresponding diameter of bore of casing	do	10.495
Number of lands and grooves		15
Width of lands and grooves	inches	0.83776
Depth of grooves	do	0.075
Twist uniform, one turn in 40 feet.		
Weight of gun	pounds	16,020
Counter-preponderance	do	189

BRONZE.

Bronze for cannon consists of 90 parts pure copper and ten parts pure tin, allowing a variation of 1 part of tin more or less. If the mixture is well effected, the metal is nearly homogeneous, fracture uniform in grain and even in color. The specific gravity of bronze is about 8.750, being greater than the mean of the metals of the alloy.

Pure copper is of a red color and fine metallic luster. Cast copper has an even grained fracture; forged bar copper shows a short, even, close

grain and silky appearance; it is strong, very ductile, and very malleable according to its purity. Specific gravity from 8.600 to 9.000.

Pure tin is of a white color, a little darker than silver, very malleable, and susceptible of being rolled into thin sheets, soft and not very ductile. In rods or bars on being bent it gives a peculiar creaking sound, distinct in proportion to its purity. Specific gravity, 7.290 to 7.320.

All *bronze* should be rejected which contains sulphur in an appreciable amount; which contains more than about one-thousandth of arsenic and antimony; more than about three-thousanths of lead, iron, or zinc; or, in all, more than about five-thousandths of foreign substances.

*Management of bronze.**—The circumstances of chief difficulty and importance in the manipulation of bronze affecting the production of cannon are—

1st. The chemical constitution of the alloy as influencing the balance of hardness and tenacity.

2d. Its chemical constitution and other conditions influencing the segregation of the cooling mass of the gun when cast into two or more alloys of different and often variable constitutions.

3d. The effect of rapid and slow cooling and of the temperature at which the metal is fused and poured.

4th. The effect due to repeated fusions and to foreign constituents in minute proportions entering the alloy.

In bronze, sufficient hardness must be secured to resist longest the abrasions of projectiles and deflagration of powder; along with the greatest ultimate tenacity, there must be certain rigidity and ductility with ultimate cohesion; hardness and rigidity increase with the proportions of tin; ductility and tenacity with that of the copper, but not in direct ratio; specific gravity increases with copper. The fusibility is greater than copper, and less than tin; ultimate cohesion less than that of tough copper, but greater than that of tin; ductility greater than tin, but less than copper; hardness greater than either.

In consequence of the difference in the fusibility of tin and copper, the perfection of the alloy depends much on the nature of the furnace and treatment of the melted metal. By these means alone the tenacity of bronze has been carried at the Washington navy-yard as high as 60,000 lbs.

THE FABRICATION OF BRONZE GUNS AT SOUTH BOSTON FOUNDRY.

The first step in the fabrication at the foundry is to make an accurate working drawing of the gun, on a convenient scale, showing all lines clearly and with all its dimensions distinctly marked, as in Plate XXXI.†

The subsequent steps vary according to the method proposed to be used in casting. Formerly bronze guns were cast in loam or sand molds, but these have been superseded by a thick mold of cast iron, called a chill. When cast in chills, bronze is denser, stronger, and more uniform than in sand; there is less liability of a separation of tin, or forming of a tin-copper alloy differing from bronze.

A description of the process of casting in sand will supply details required for an understanding of the chill-casting.

When a casting is desired in sand, a wooden pattern of the gun is made, following the shape of the drawing, but larger in all its dimensions, both by the shrinkage of the casting and also by the amount al-

* Mallet.

† A drawing of the gun made on a smooth board, full size, the dimensions taken from the draught, is also laid down if desired.

lowed for finishing, of never less than one inch over the finished diameter. The pattern is also made longer than required for the gun-casting, to form a sinking-head of a diameter about equal to that of the gun at the muzzle, and with a volume or weight, for ordinary guns, about one-third that of the whole casting. This sinking-head supplies fluid metal to the casting as the latter cools, and receives any cinder or dross that would otherwise remain in and injure the casting. The sinking-head is cut off as soon as practicable after casting.

The *pattern* is formed by planing the surfaces of moderately thick, clear plank, and gluing pieces of different widths together, the widest next the center of the pattern, until a sufficient thickness is obtained for each half the entire pattern, divided longitudinally. Two or more steadying-pins are then fixed in one half of the rough pattern, with corresponding holes in the other half, the surfaces having been fitted neatly to each other. The halves are clamped firmly together, carefully centered and turned in a lathe to the proper dimensions. All projecting parts not annular must be attached to the pattern in separate pieces fitted to the turned surfaces of the partly finished pattern. Thus, separate pieces are turned for the trunnions, including the rimbases, the sight masses, &c., and fastened to the pattern in their proper positions by pins in the wood, so that they may be readily removed.

The whole pattern is carefully finished and smoothed with sand-paper, the angles and corners well rounded, and varnished to protect the wood from the moisture of the sand. The pattern and loose pieces are legibly marked.

The *flask* is longer than the entire pattern including the sinking-head, and contains sufficient sand around the pattern to permit proper ramming and to make the mold sufficiently secure, leaving room enough for the runner or gate at the side of the pattern. The flask is of hexagonal shape, divided longitudinally in two parts; each half has strong longitudinal flanges, and is strengthened crosswise by ribs running from flange to flange. Each side of the half flask which adjoins the flange is solid, but the third side, which lies uppermost in molding, is open save where the ribs cross it. This opening from one end to the other is for ramming, and is closed by movable plates, which are held down upon the sand by means of wedges driven under the ribs.

For *molding*, half of the pattern is laid upon a flat surface—"follow-board"—which is somewhat larger than the flask. The latter is placed over the half pattern. Well-tempered sand mixed with clay and beer lees is then rammed uniformly all around and over the pattern, so as to be of equal density and hardness throughout. The loose plates are then keyed down, the flask raised and turned over, and the surface of the sand closely sprinkled with fine, unadhesive parting sand. The second half of the pattern is laid exactly on the first and kept in place by the steadying-pins; the other half of the flask put on, keyed to its fellow, filled with sand, and rammed evenly round as before and its plates keyed down. The two halves of the flask are then separated, the pattern removed, the main runner cut with a suitable tool along the sand on the surface where the flasks part, being made funnel-shaped at the top. Half the runner lies in each part of the flask, the main gate is cut from the bottom of the runner into the mold and other gates above it. The main gate is cut tangent to the circumference of the mold, that the metal as it rises may receive a rotary motion. The mold is put into a drying oven, raised to a high heat, 300 degrees or more, and thoroughly dried. The whole surface of the sand mold is carefully coated with a wash of graphite, fire-clay, and molasses and water, and

the mold dried again for a few hours. When it is ready for the casting the flask is placed in the pit upright on end.

When a chill is used, the process is as follows: The chill conforming to the curves of the pattern unites the functions of the flask and of the sand mold, and by its high conducting power rapidly extracts the heat of the metal cast within it.

The working draft of the gun being made as before, a drawing of the chill is made giving the dimensions required. From this the pattern is prepared, so much being added to every dimension, that when cold after casting the interior sizes of the chill may be those required by the casting of the gun. The chill is best divided longitudinally into halves on a plane at right angles to the trunnions, and also horizontally into two, or, if the gun is long, into more sections, the lower two of which, one on each side, sections *a* and *b* of Fig. 1, Plate XXXII, contain the recesses forming the trunnions and rimbases. Four pieces, *a*, *b*, *d*, and *e*, are provided with flanges for clamping them together. An additional section, *c*, added for the cascable, is made with a broad flange upon which the whole chill when keyed together securely stands. The gun casting proper is thus inclosed in a cast-iron mold, and is quickly chilled. The sinking-head *g* is molded in dry sand, that it may remain liquid to feed the casting as long as possible.*

The pattern for the sinking-head is a cylindrical piece of wood, of proper diameter and length, which is placed within a long cylindrical flask, open at both ends, and withdrawn after the sand has been rammed around it. This flask, or "pot," is made, fitted, and fastened to the top of the chill.

Two patterns are requisite for the chill proper and one for the base. They are made from the proper drawing like those for ordinary sand castings, the internal dimensions being fixed as in the method previously described, by the shrinkage of the alloy and the amount left for finishing. The walls of the chill may be from 2½ to 3½ inches thick. After the castings are made they are carefully smoothed or bored out when practicable; and all corners, especially in the trunnion molds, likely to retain gas or to catch dross in casting are carefully smoothed over and rounded.

When a casting is to be made, the parts of the chill *a*, *b*, *c*, *d*, and *e* are cleaned, fastened together, covered inside with a wash of fire-clay, molasses and water, and heated to a moderately high heat in an oven.

At casting, the chill is brought out and the sinking-head mold keyed to it.

The metal may be poured direct into the mold or through a separate runner at the side opening into the chill at the bottom, as in Fig. 2, Plate XXXII. If poured direct the stream falls from the top straight downward from a small box lined with sand, which receives the metal from the ladle. If a side runner is used it is divided longitudinally, the halves are fastened together by flanges and bolts. The base of the chill is fitted to receive the runner, which is, at the bottom, contained in a cast-iron box bolted to the chill and leading horizontally into the opening. Each half of the pipe receives the sand for the runner, which is also molded as above and dried in an oven.

The side runner has the advantage of keeping the metal cleaner in the casting through the rotary motion imparted by the stream flowing into the mold tangentially, but it is apt to leave the sinking-head too cool, and hence the latter is, in any case, best poured direct after

* When the metal is poured direct, good results are obtained when the sinking-head is cast in a chill section instead of the sand mold.

the mold or chill has been filled above the top of the gun. The side runner is shown by *h*, Fig. 2, Plate XXXII, with its funnel top *i*, and the cast-iron base box *k*.

For casting, it is most convenient to place the chills or flasks in a pit, *p*, Plate XXXIII, in such a position as to be easily reached by the crane ladle *o*, used for pouring. The pit may contain several chills at once, and the crane *m* commands both the furnace and the pit. As soon as the bronze is melted the ladle is brought beneath the tapping hole *n*, the metal tapped into it, and the ladle swung around over the chills.

The furnace r is a reverberatory furnace (Plate XXXIV) fired with soft bituminous coal so constructed that the metal as it melts runs into a pool at the end furthest from the fire, thus removing it from the immediate action of the flame. The bottom of the furnace is made of fire-clay rammed hard. A door, Q, of convenient size, is placed in the side of the furnace for charging, taking samples of molten metal for test, &c., and the tapping hole is usually placed under it for convenience of access.

The furnace is charged by laying the metal selected, which may be either old guns or sinking-heads, or new copper, or chips from the lathe, on boards on the bottom of the furnace, distributing it carefully so as to expose all pieces properly to the flame, that they may come into fusion at about the same time. The copper is charged as bought in pigs, but guns and heads are cut up into pieces of convenient size. The tin is charged in the shape of small ingots recast for the purpose, about 12 inches long by ½ inch square.

The composition of the charge is varied to suit the metal used, but the total weight must be sufficient to cast the gun and sinking-head and leave some surplus. For the 3½-inch rifle cast in 1876, the charge was as follows:

	Pounds.
Old guns cut up	2,650
New copper, in ingots	830
Tin, in small bars	104
Total	3,584

The whole casting weighed 3,126 pounds, for a finished weight in the gun of 1,322 pounds. The riser when cut off weighed 700 pounds, and there was a waste in the furnace of 1.6 per cent.

A second gun of the same model was cast from old guns with the following charge:

	Pounds.
Old guns cut up	3,224
Tin	40
Total	3,364

The casting weighed 3,217 pounds, the riser 650 pounds, and the waste was 1½ per cent.

Melting the charge.—After the old bronze or copper has been charged, the furnace is closed and fired up gently at first and more strongly as the metal sinks down away from the flame, which must always be kept smoky, *i. e.*, of a reducing character. When the bronze or copper is melted the tin is added; it is thrown into the bath at different points and worked under the surface as much as possible as it floats bouyantly till alloyed. The bath may be stirred thoroughly with an iron bar, or, if much old metal be used, with a pole of green wood.

After the metal is wholly melted it is kept in fusion for some time—

about half an hour—in order that a thorough alloy may be effected, and a proper temperature be reached for casting.

The alloy is examined for its cold fracture by means of specimens taken out of the furnace in a small ladle. When the fracture is brought to the proper yellow-red color, judged by experience, and the heat has reached the proper point, the bronze is ready for casting.

For the first gun above quoted, the furnace was lighted at 8 a. m., the metal melted at 10.25 a. m., and the casting made at 11.30 a. m., or in 3 hours and 30 minutes in all.

For the second gun the melting occupied 1 hour and 50 minutes, and the metal was kept in fusion 70 minutes; that is, the heat was cast 3 hours in all from the time the fire was lighted.

The character of the sample taken from the sinking-head of the 3½-inch rifle casting, next the muzzle, was as follows:

Locality.	Tenacity.	Density.
Outside specimen	48,230 pounds per square inch	8. 6663
Inside specimen	37,706 pounds per square inch	8. 5651

The tendency of bronze to separate into alloys of different composition is so strong that specimens taken at different heights in the mold exhibit very different densities and strengths. A series of specimens cast in the same sand mold with the gun and contiguous to it, but separate from the gun-casting proper, showed a constant decrease of strength from the cascable to the sinking head.

Average.	Bottom of sinking-head.	Side specimen A.	Side specimen B.	Side specimen C.	Finished gun as a whole.
Density	8. 440	8. 597	8. 660	8. 686	8. 649
Tenacity	26, 760	39, 364	41, 974	43, 062	....

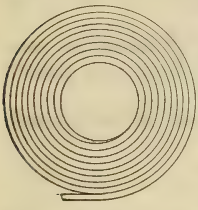
The average density of one hundred and twenty-four 24-pounder bronze howitzers, made for the Navy Department in 1863 and 1864, between the South Boston foundry numbers 1417 and 1693, was 8.722, and average tenacity 50,041 pounds per square inch. This is the best series the company has reached. The averages of forty-five guns, from No. 434 to 478, inclusive, were density 8.653, and tenacity 33,665 pounds per square inch.

On the other hand, nine guns included in the first series, and made between foundry numbers 1556 and 1615, exhibited an average density of 8.804, and an average tenacity of 60,610 pounds to the square inch.

THREE-INCH WROUGHT IRON FIELD RIFLE.

These guns were manufactured at the Phœnix Iron Works, Pennsylvania, in the following manner: Rolled staves, ⅞ by ⅞ inch by 4½ feet long, were laid up in the form of a barrel on an arbor which was placed in a lathe. A long bar, ¾ by 4½ inches—a rhomboid in section—was wound spirally upon the barrel by the revolution of the lathe. Another bar was wound upon the first, the spirals running in an opposite direc-

tion, and so on until five layers had been applied. A thin layer of staves was then bound upon the outside, and a plug driven into the breech to close it and to form the cascable. The whole was then heated to welding, and upset endwise two inches in a press, after which it was drawn out between the rolls from 4½ to 7 feet in length. The trunnions were then welded on, without removing the gun from the reverberatory furnace; the bore was dressed out, and the chase reduced to the proper size by turning, the mass being cylindrical when it left the rolls. The above process has now been abandoned, a cheaper and sounder gun, it is claimed, being made as follows: A sheet of iron is rolled around a mandrel into a cylinder, and drawn down into a tube with solid walls. The bore may be made entirely within the mandrel, which may be of steel. The seams in this case would not weaken the gun—indeed, the mere sticking of the iron together would prevent its uncoiling under fire. And the iron may be refined before it is made into a gun.



1.65-INCH BREECH-LOADING MOUNTAIN GUN, HOTCHKISS.

(Plate XXXV.)

This gun, having been devised especially with reference to the mountain service, is made as light as practicable. It weighs only 116.6 pounds, and one man is able to place it upon the back of a mule. The weight of the carriage being but 220 pounds, the packing, unpacking, and mounting of the gun and its carriage require only two men.

For transportation the material is distributed as follows: One mule carries the piece and two small chests containing accessories; another mule carries the carriage and shaft, and two others carry the ammunition chests.

The construction of the Hotchkiss gun is based upon the use of a metallic cartridge, by which the obturation of the breech is accomplished. The extraction of the cartridge case is effected automatically by the opening of the breech.

The gun is made of Whitworth steel, compressed in the fluid state. The mechanism of the breech consists simply of a prismatic bolt, with a cam, entering a cavity recessed in the breech. It is operated by a lever with handles, by which the bolt is withdrawn, or the reverse.

As metallic cartridges are employed, a close fit of the breech block is unnecessary, and the bolt is therefore adjusted freely to its slot, which is an advantage over other breech-loading systems, which require great nicety in the fit of the breech mechanism in order to insure a perfect obturation.

The cartridge-extractor is a simple prismatic piece of metal, bearing at its forward extremity a hook; it is guided in a cavity in the upper part of the breech, parallel to the axis of the piece; on its lower face is fitted a tenon, which slides in a groove cut in the upper face of the breech-block. The groove is straight on the side towards the handle, but curved at the other extremity—towards the opening for charging—so that in withdrawing the breech-block the tenon of the extractor slides for a time in the straight part of the groove, but as soon as the block is so far withdrawn that the opening for charging comes against the face of the chamber the tenon becomes engaged in the inclined portion of the groove, and is suddenly drawn backwards, by which motion the empty case is

thrown out of the gun. The movement of the breech-block is arrested by a stop-screw sliding in a recess upon the upper face of the block.

The ammunition is composed of a metallic case which contains the powder, and is united to the projectile—an explosive shell—by "choking," in the same manner as the cartridges for modern small-arms. The cartridge-case is of brass; the head being strengthened by cup-shaped reinforces. It is not primed, but is ignited by the ordinary friction primer. In the base of the cartridge is a valve formed by the cup reinforces; the gas from the primer opens the valve, which closes automatically, after the ignition of the charge, by the pressure of the gas inside, thereby preventing the escape of gas through the vent. The cartridge-case can be re-charged, on an average, about eight times. The projectile is of a cylindro-ogival form, about 3½ calibers in length; it is furnished with a middle band of soft brass, which takes the rifling. Upon the cast-iron body of the projectile are turned a number of grooves, of little depth and width, between which are narrow and sharp ridges. The band covers this portion of the projectile, and at the moment of firing the pressure of the gas which surrounds the projectile in the chamber molds exactly upon the brass the corresponding grooves and ridges that are on the cast iron.

This method of banding offers the advantage of securing a perfect adherence between the brass band and the projectile, and also permits regulating with great nicety the forcing whereby the friction necessary to produce rotation may be reduced to a minimum. The band of brass obviates the fouling of the bore, so that the piece can be fired a great many times without any necessity for using the sponge.

The shells are fitted with percussion fuses of the Hotchkiss pattern.

PRINCIPAL DIMENSIONS.

Total length	inches..	45.87
Total length of bore	do....	41.80
Caliber	do....	1.65
Number of helicoidal grooves		10
Twist (to the right)	inches..	49.21
Depth of grooves (uniform)	do....	0.12
Total weight of piece	pounds..	116

DIMENSIONS OF CARTRIDGE.

Length of shell	inches..	5.90
Length of case	do....	6.02
Total length of cartridge	do....	9.19
Length of cavity in shell	do....	3.65
Diameter of cavity	do....	1.02
Diameter of shell in front of band	do....	1.625
Diameter of shell in rear of band	do....	1.637
Width of band	do....	1.76
Exterior diameter of cartridge-case	do....	1.81

CARTRIDGE.

Weight of empty shell	lb. oz..	1.10¼
Weight of bursting-charge	ounces..	1.76
Weight of percussion-fuse	do....	3.52
Weight of loaded shell	lb. oz..	2.10
Weight of empty cartridge-shell	ounces..	5.47
Weight of powder-charge in cartridge	do....	5.5
Weight of cartridge and loaded shell	lbs. oz..	2.11
Initial velocity	feet..	1,275

SERVICE OF THE PIECE.

Two cannoneers are sufficient for maneuvering it. The cannoneer on the right opens and closes the breech, primes, and fires; the one on the left supplies the ammunition, introduces the charge into the bore, and points.

To open the breech, turn the handle a half turn, from right to left, and draw out quickly the block till it strikes against the stop-screw.

Loading.—The loading is done by inserting the cartridge into the chamber and pushing it forward until the flange strikes against the extractor-hook. After that, close the breech.

To close the breech, execute the movement for opening it inversely.

THE HOTCHKISS REVOLVING CANNON.

(Plates XXXVIII, XXXIX.)

THE GENERAL SYSTEM.

The Hotchkiss revolving cannon cannot be classed with mitrailleuses in the ordinary sense of the latter term, as explosive shells are fired with the former, and it has a range equal to that of field artillery.

The system of this gun may be explained as follows:

Five barrels grouped around a common axis are revolved in front of a breech-block, which has in one part an opening to introduce the cartridges, and another through which to extract the empty shells.

The exterior aspect of this revolving cannon resembles the Gatling mitrailleuse, it being, however, entirely different in its interior mechanism. The system is composed of two distinct parts, viz, the barrels with their disks and shafts, and the frame and breech containing the mechanism.

The five barrels, made of the finest oil-tempered cast-steel, are mounted around a common axis between two disks on a central shaft. The series of barrels are placed in a rectangular frame, which is attached to the breech, the near end of the shaft penetrating the same to receive the rotary motion from the driving gear.

The breech itself is composed of a solid cast-iron breech-block, weighing 175 kilograms (385 pounds). This absorbs the greater part of the recoil. It has a door at the rear end, which can be easily opened, so that the mechanism is accessible, and can, if necessary, be taken out and put in place in a few minutes without the aid of any special tools.

A peculiar feature in this gun consists in the barrels remaining still during the discharge, so that there is no movement of any kind to impede the accuracy of fire. This stop or lost motion is obtained by the shape of the driving-worm, which is so constructed that the inclined driving-thread only covers half of its circumference, the other half of the thread being straight. The effect of this is, that the barrels only revolve during half a revolution of the worm, and stand still during the other half revolution. The combination of the mechanism is so arranged that the loading, firing, and extracting take place during this pause. This feature is of great importance for the accuracy of fire and the durability of the system.

The worm shaft projects through the breech on the right side, and has a crank with which the whole system is moved; on the left side of the

worm shaft a small crank is attached, by which the loading and extraction of the cartridge shells are effected in the following manner:

On the interior face of the left side of the breech a cog-wheel is mounted with two horizontal racks, the one being placed above, the other under, the cog-wheel, and parallel to the axis of the barrels, so that in moving one of these racks the other is moved in the opposite direction. Part of the lower rack forms a vertical slot, in which the small crank on the left side of the worm shaft works. The rotation of the latter, consequently, gives an alternating and opposite movement to the two racks, so that while the one is going forward the other moves back and reciprocally.

The under rack works the extractor; the upper one moves a piston, which drives the cartridges into the barrels, the cartridges being placed before the piston, in the trough, in which it moves; and during the time the barrels are motionless it is introduced into the one standing before the trough. The cartridge is not "driven home" entirely, but its head is in view of an inclined plane cut into the metal of the breech, on which it slides when it is moved by the rotation of the barrels. This completes the introduction of the cartridge into its chamber. The piston itself is a simple cylinder connected with the rack, and running in a slot in the conducting trough.

When the racks are in their extreme positions they remain still a moment. This stop is obtained by giving the slot in its center part a circular shape concentrically to the shaft of the crank. This is necessary, because at the moment of the barrels arriving at the end of their course the head of the cartridge-case becomes engaged in the hooks of the extractor, which would not be possible if it were in motion at the time.

The extractor is a large double hook at the end of the bottom rack; it is very solid, and its proper working is certain under all circumstances. After the cartridge is extracted from the barrel it strikes against an ejector, which pushes it out of the extractor, and falls to the ground through an opening in the under part of the breech. The firing-pin has an elongation, pointing downwards, which, by the operation of a spring, is pressed against a cam on the worm, and, as the worm rotates, the cam drives the firing-pin back and compresses the spring. The moment the firing-pin becomes liberated it strikes the primer of the cartridge and the discharge takes place.

To obviate the difficulties of feeding, which exist in other systems, when the cartridges are piled one upon the other, the opening of the introduction trough is closed by a little door, which goes down by the weight of the cartridges, the first of which drops into the trough, and then the piston moving forward, raises the door, and allows no more cartridges to enter until the proper time.

All parts of the mechanism are very strong and durable, and hardly exceed in number those of an ordinary small-arm, there being besides the group of barrels thirteen parts, viz:

1, 2. The breech-block with its door for closing the rear end.

3, 4, 5. The crank-shaft, with its worm for moving the barrels, and small crank for working the loader and extractor.

6. The crank.

7, 8. The firing-pin and spiral spring.

9. The extractor.

10, 11. The loading-piston and rack for moving it.

12. The cog-wheel for transmitting the movement of the extractor to the loading-piston; and

13. The door for regulating the feed of cartridges.

THE OPERATION OF THE MECHANISM, ETC.

The operation of the mechanism is as follows, supposing the crank to be in continual motion:

A cartridge is placed in the introduction-trough, the piston pushes it into the barrel, the barrels begin to revolve, and the cartridge is carried on till it arrives before the firing-pin held in the solid part of the breech, and which has in the mean time been retracted by the action of the cam. As soon as the cartridge has arrived in this position the barrels cease to revolve, and the primer of the cartridge is struck by the firing-pin and discharged; the revolution of the barrels begins again, and the fired cartridge-shell is carried on until it comes to the extractor, which in the mean time has arrived up to the barrels, and the cartridge-head rolls into it. As soon as the head is laid hold of by the extractor the barrels again cease to revolve, and during this period the cartridge-shell is withdrawn and dropped to the ground. During every stoppage of the barrels the gun is supplied with a new cartridge, the firing and extraction are also performed, and a continuous but slow fire kept up.

Supplying the gun in this manner with single cartridges, about thirty rounds per minute may be fired.

Should *rapid* firing be required the gun is supplied with "feed-cases" containing ten cartridges each. In this manner from sixty to eighty rounds per minute can be fired, with only three men to work the guns, viz, one man to train the gun and revolve the crank, one man to place the "feed-cases" containing the cartridges into the "feed-trough," and a third at the ammunition chest to charge the "feed-cases" and to hand them to the loader.

Attached to the frame is a "turn-table," which connects the cannon to the "trunnion saddle," arranged in such manner that without displacing the carriage a certain amount of lateral motion, as well as of elevation, may be given to the gun. Thus the gun is made to sweep horizontally, by adjustment, between each single shot, or during rapid discharge.

Principal dimensions, and weights, &c., of the gun.

Caliber	inches..	1.45
Total length of bore	do....	50.236
Length of rifling	do....	44.882
Rifling, one turn in	do....	49.212
Twist and depth of grooves uniform.		
Number of grooves		12
Width of lands	do....	0.098
Depth of grooves	do....	0.019
Number of barrels		5
Diameter of barrel over the powder-chamber	do....	3.464
Diameter of barrel at the muzzle	do....	2.440
Weight of each barrel	pounds..	77.166
Radius of sights	inches..	27.047
Vertical distance of the line of sight from the common axis of the barrels	inches..	2.0866
Horizontal distance of the line of sight from the common axis of the barrels	inches..	6.496
Weight of gun	pounds..	1047.25
Total weight of gun with traversing apparatus	do....	1157.48

HOTCHKISS REVOLVING CANNON, LIGHT FIELD MODEL, CALIBER 1.45 INCHES.

This gun differs from the one previously described in minor details only, the construction being the same; the gun is lighter and the barrels are shorter.

The ammunition used with this gun is also lighter and shorter than that used with the heavier model, but alike in all other respects.

The principal weights and dimensions are:

Total length of bore	inches..	29.125
Weight of gun	pounds..	495
Charge	ounces..	2.63
Weight of cartridge, complete	do....	21.54
Length of cartridge, complete	inches..	6.57

GATLING GUNS.

Plates XXXVI, XXXVII.

DESCRIPTION.

The Gatling gun consists of a number of very simple breech-loading rifled barrels grouped around and revolving about a shaft to which they are parallel. These barrels are loaded and fired while revolving, the empty cartridge-shells being ejected in continuous succession. Each barrel is fired only once in a revolution, but as many shots are delivered during that time as there are barrels, so that the ten-barrel Gatling gun fires ten times in one revolution of the group of barrels. The action of each part is therefore deliberate; while collectively the discharges are frequent. The working of the gun is simple. One man places one end of a feed-case full of cartridges into a hopper at the top of the gun, while another man turns a crank by which the gun is revolved. As soon as the supply of cartridges in one feed-case is exhausted another case may be substituted without interrupting the revolution or the succession of discharges. The number of barrels composing the gun as originally made were ten. The bore of each barrel extends through from end to end, and the breech is chambered to receive a flanged center-fire metallic case cartridge. The breech ends of all the barrels are firmly screwed into a disk or rear barrel-plate, which is fastened to the shaft, and the muzzles pass through another similar disk, called *front barrel-plate*, on the same shaft. The shaft is considerably longer than the barrels, and projects beyond the muzzles, and extends backward for some distance behind the breeches of the barrels.

Directly behind the open barrels a cylinder of metal, called a *carrier-block*, is fastened to the shaft, and in the exterior surface of this carrier-block ten semi-cylindrical channels are cut, which form trough-like extensions of the cartridge-chambers of the barrels to the rear, and are designed to receive and guide the cartridges while they are thrust into the barrels, and to guide the empty cases while they are withdrawn. Behind the carrier-block the shaft carries another cylinder, called the *lock-cylinder*, in which ten guide-grooves are formed, which are parallel to the barrels, and in which slide ten long *breech-plugs* or *locks*, by which the cartridges are thrust into the barrels, and which close the barrels and resist the reaction of the charges when they are fired. Each plug or lock contains a spiral mainspring acting on a firing-pin, by which the charge is fired, so that the plug performs all the functions of a gun-lock as well as of a breech-plug. The shaft to which the group of barrels and both the carrier-block and the lock-cylinder are rigidly attached is free to turn on its axis, the front end being journaled in the front part of the frame and the rear end in a diaphragm in the *breech-casing*. The breech-casing extends to the rear far enough to contain not only the *diaphragm* through which the main shaft is journaled, but also to form in the rear of the diaphragm a cover for the gearing by which the shaft

is revolved. This mechanism or gearing consists simply of a toothed wheel fastened to the shaft and worked by an endless screw on a small axle which passes transversely through the case at right angles to the shaft, and is furnished outside the case with a hand-crank. A cascabel plate closes the end of the plate.

Each lock carries a hooked *extractor*, which snaps over and engages the cartridge-flange when the lock is pushed forward, and which, when the lock retreats, withdraws and ejects the empty case. The *cartridge-carrier block* is covered above the frame by a semi-cylindrical shell, which is provided at the top with an opening of suitable size and shape to permit a single cartridge to fall through it into one of the channels of the carrier-block which it overlies. There is a trough extending upward from this opening and forming a *hopper*, in which a straight feed-case can be placed in a vertical position, containing a number of cartridges lying lengthwise across the case, one above another. Beneath the *carrier-block* everything is open so as to allow the cartridges or shells which are withdrawn by the extractors from the barrels to fall to the ground. Within the cylindrical breech-case attached to the frame a heavy ring not quite the length of the lock-cylinder is fastened to the case and diaphragm, which nearly fills the space between the inside of the case and the cylinder. Portions of the inside of this ring are so cut away as to leave a truncated, wedge-shaped, annular or spiral *cam* projecting from the inner surface of the ring, having two helicoidal edges inclined to each other and united by a short, flat plane. Against these edges the rear ends of the locks continually bear, there being room enough for the locks to lie loosely within the parts of the ring which are cut away. The apex of the wedge-shaped cam points to the barrels. Each lock is held back against the cam by a lug or horn projecting laterally from the end of the lock and entering a groove formed at the base of the cam, in the thin part of the ring.

The shape and position of the cam and grooves may be better understood by reference to the diagram, which shows the cam-ring as it would appear if cut open and spread out flat, the lines A and C being the development of the edges of the helicoidal cam surfaces, B that of the plane surface connecting these, and *a* and *c* the grooves for holding and drawing back the locks. The ten locks are shown in their relative positions abutting against the cam surfaces, six of them being shown in section.

It will be seen that the points of the firing-pins H protrude beyond the front of the locks while the other ends project from the rear, where they are fashioned into knobs, by which the firing-pins are drawn backward while passing through the groove in the *rib* D.

The diagram shows that the distance of the apex B of the cam from the ends of the barrels is such that the locks exactly fill the space so that each lock there forms an abutment which closes the breech of its barrel and abuts against the apex of the cam, which serves to resist the recoil of the lock when the charge is fired.

The position of the cam relatively to the cartridge-hopper is such that each lock is drawn backward to its full extent when it passes the hopper, so that the cartridges may fall into the carrier in front of the locks. The explosion of each cartridge takes place as its proper lock passes over the flat apex of the cam which resists the recoil.

The firing-pin is drawn back by the head at its rear end engaging with a flat *rib* located inside of the cam, as shown on the diagram at D. This rib restrains the firing-pin from moving forward, while the forward movement of the body of the lock continues; the spiral mainspring is

compressed until the revolution carries the firing-pin head beyond the end of the cocking-rib, when the firing-pin will spring forward and strike with its point the center of the cartridge-head and explode the charge. The point in the revolution at which the barrels are discharged is below and at one side of the axis. The diagram shows the ten locks each in a different part of its cycle of action. At I the cartridge has just dropped in front of the lock; at II it has been pushed forward somewhat; at III the point of the cartridge has entered the barrel; at IV it is pushed nearly home, and the head of the firing-pin is retained by the cocking-rib H, the mainspring being partly compressed; at V the lock has reached the flat part of the cam, the cartridge is pushed quite home, and the mainspring has been fully compressed by the retention of the firing-pin by the cocking-rib, the end of which is just reached by the firing-pin which is about being released; at VI the firing-pin having been released has sprung forward and exploded the cartridge, the end of the lock being firmly braced against the flat surface B of the cam; at VII the lock has commenced to retreat, and at VIII it has partially withdrawn the empty cartridge-shell from the barrel; at IX it has completely extracted the shell, which is falling away from the gun; at X the lock is fully drawn back and is about to pass again into its first position. Thus it will be seen that in the ten-barrel gun one revolution of the barrels corresponds to one revolution of the locks and delivers ten shots, a process which is repeated continuously so long as the crank is turned and the cartridges supplied. The gun can be unloaded of any cartridges not fired by removing the feed-case, opening the hopper, and reversing the motion of the crank. In the new model the mechanism of the locks has been greatly strengthened, as well as otherwise improved, and there are means provided for their insertion and removal without taking off the cascabel-plate. These means consist of the perforation of the covering and back diaphragm in the outer casing, and by the closure of the apertures through both these plates by a single removable plug, as shown above the knob of the cascabel. The absence of one or more locks does not affect the working of the gun except to diminish the intensity of fire in proportion to the number of locks removed.

For each lock removed, however, one unexploded cartridge falls to the ground at each revolution of the gun. The gun is incased in a frame which has trunnions, and is mounted in the ordinary way, like a field-piece. The screw for elevating and depressing the breech works in a nut attached to the trail of the carriage in the usual way. An automatic traversing apparatus is applied, by which a limited angular movement in a horizontal plane may be given to the gun, as follows: A cylinder having a cam-groove in its periphery is applied to the crank-axle, and the end of a cylindrical pin enters this groove. The cylindrical pin is attached to an arm which is connected to the elevating-screw; when the crank is turned the cam-groove travels back and forth on the cylindrical pin, swinging the gun from side to side through a sector of three degrees. The pin may be thrown out of gear with the cylinder and the gun be fired without swinging. The sector, covered automatically by the traverser, may be changed about five degrees on each side without moving the trail or suspending the firing.

Straight feed-cases.—The cases which contain the cartridges, and which are applied to the hopper when it is desired to feed the gun, are long, narrow boxes of sheet-tin, reinforced by gun metal, open only at the lower ends. The cross-section of the case is trapezoidal, the edge next to which the heads lie being wider than the cartridge-heads, while that which receives the points of the balls is of the width of the ball.

This form enables all the cartridges in the case to assume a horizontal position, because the heads of the contiguous cartridges have room to roll over slightly, so as to lie partly alongside of each other, while the ball-ends are kept vertically over each other. Above the cartridges in the case is a weight which can be moved up and down by a thumb-piece. By the action of the hand pressing on the thumb-piece any desired pressure, regulating the uniformity of feed, can be given to the cartridges. Each straight feed-case contains forty cartridges. The supply of cartridges to the gun may also be made by what is called the "feed-drum."

The improvements in the gun intended for service with cavalry consist in a change of the position and attachment of the crank from the side to the rear, greatly facilitating and increasing the speed of revolution of the gun and rapidity of its fire; the feed-cases are entered more readily to the receiver, and stand vertically, thus insuring a direct fall and feed of the metallic cases; the exterior form of the receivers admits of reversing the motion of the crank without danger of jamming the cases. All the working parts, as well as the barrels, are incased in bronze, affording better protection from dust and dirt to the gun. It is lighter and of less expensive construction and more compact in appearance. An automatic device attached to the breech of this gun gives a traversing motion through a small angle, which can be set to suit range and circumstances of fire and is worked by the crank operating the gun. The increased rapidity of fire is more than double that of the old model ten-barreled gun, and its accuracy is by no means impaired.

A new model Gatling gun is mounted on a cast-iron turn-table, the shaft of which fits a hole in the bed-plate of the carriage or tripod. It is provided with a long lever working through a stirrup attached to the casing, to which is attached a sliding wedge. By releasing a set-screw and pressing the handle the wedge is released, and any elevations to 15° and depressions to 30° given; a flat spring under the handle holds the wedge in place. The gun is traversed by turning the handle and held in position by a clamp-screw.

The cascabel-nut is provided with a set-spring, by means of which the space for heads of cartridges is increased or diminished for variable thicknesses in flanges of cartridges.

Weights of the Gatling 10-barrel guns.

	Pounds.
1-inch caliber	650
0.50 inch; 0.45 inch caliber, with long barrel	200
Same calibers with short barrels	135

THE 12.25-INCH MUZZLE-LOADING RIFLE.—EXPERIMENTAL.

Plate XL, Figs. 1 and 2.

DESCRIPTION OF THE GUN.

The cast-iron body or casing of the gun has the same dimensions, externally, as those adopted for a 12-inch cast-iron rifle, model of 1874. (See Report of Chief of Ordnance, 1877.)

The details of the coiled wrought-iron tube conform in the general plan of its construction to the 8-inch converted rifle, wrought-iron lined, a full description of which has been given previously. Four securing-pins are used to prevent the tube working in the casing.

RIFLING.

The rifling consists of 21 lands and grooves, each of equal width.

Width of lands and grooves	0.9163 inch.
Depth of grooves	0.09 inch.

Twist uniform, one turn in 70 feet.

The full depth of the rifling stops at a point 20 inches from the bottom of the bore, and the grooves are terminated with a uniform bevel 2 inches in length.

VENTING.

The vent is located parallel to the vertical plane through the axis of the bore and 3 inches to the left. It enters the bore at 9.5 inches from the bottom.

FABRICATION.

The tube was manufactured at the works of Sir William Armstrong at Newcastle-upon-Tyne, England. It is of coiled wrought iron, and made upon the same plan as those used in the conversion of the 10-inch Rodman smooth-bores into 8-inch rifles. It was bored up to an interior diameter of 12.227 inches, in order to remove a defect found in the bore while in progress of manufacture.

The diameter and length of tube when received were considerably in excess of the prescribed finished dimensions. It was subjected with satisfactory results to a water-proof of 375 pounds per square inch, and a careful inspection failed to discover any flaws or defects in its construction.

The casing was manufactured and the gun finished at the South Boston foundry.

The gun-casing was cast on the Rodman plan, and cooled from the interior by a current of water. The pattern and flask for the mold were the same that were used in the construction of the Thompson 12-inch breech-loading rifle. These were altered to conform to the different exterior dimensions, and a muzzle-section 30 inches long was added to give the additional length required. A new core-barrel was provided on account of the increased diameter of the bore over the Thompson gun-casing.

FURNACES AND IRON.

The ordnance foundry in which the gun-casing was cast contains three reverberatory furnaces, all of which were charged to their full capacity. The grades and quantities of iron employed were as follows:

	Pounds.
No. 1 Dover pig iron	22,500
No. 2 Dover pig iron	22,500
No. 3 Dover pig iron	22,500
No. 1 Muirkirk pig iron	22,500
No. 2 Muirkirk pig iron	22,500
No. 3 Muirkirk pig iron	22,500
Remelted Dover and Muirkirk	47,400
Total	182,400

Each furnace was charged with equal weights of the different grades.

GUN-PIT AND FLASK.

The gun-pit in which the casing was cast is 11 feet in diameter and 22 feet in depth. The flask, when in the pit, extended about 7 feet

above the top. To conduct the metal from the furnaces to the flask the tap-hole of each furnace was connected by a runner with a common reservoir or basin for mixing the charge; thence two runners extended to the flask, connecting with side runners on opposite sides and at points about 4 feet 8 inches from the top, which was as high as the flow of metal from the furnaces could reach. To fill the flask above this height, it was arranged that a portion of the charge of one of the furnaces should be drawn off into ladles to be poured in at the top.

CASTING.

The fires were kindled in furnaces Nos. 2 and 3 at 3.30 a. m., and in No. 1 at 4 a. m., May 30, 1877. The metal was down in all the furnaces by 12.30 p. m., though No. 1 preceded the others by fully half an hour, on account of being more advantageously located for feeding the fires. Tests of the metal in fusion were made at various intervals. At 4.40 p. m. it was found to be in proper condition in all the furnaces, and they were tapped simultaneously. In 15 minutes the mold was filled to the level of the runners from the basin. The flow of metal from the furnaces was then stopped, and the connecting apertures closed. Two large ladles of metal, which had meanwhile been drawn from one of the furnaces, were quickly poured in at the top of the flask, which filled it to within 20 inches of the surface. The remaining space was filled by adding three small ladles of metal, the last one being poured at 5.45 p. m. It was found, however, the next morning, that the surface of the casting had sunk several inches during the night, and more metal was then added.

COOLING.

The water was let into the core barrel at the same moment that the furnaces were tapped, and circulated for 42 minutes at the rate of 60 gallons per minute. It was then diminished to 36 gallons per minute, at which rate the circulation was continued until shut off for the purpose of withdrawing the core barrel. Fires were lighted in the pit at 6 o'clock p. m., and were kept burning for about 60 hours. The flow of water was stopped 24 hours after casting, and the core barrel removed. The water was then injected into the gun, and after a short interval the rate of circulation was fixed at 26 gallons per minute, and continued until 118½ hours after casting, when it was shut off, excepting a small stream of half a gallon per minute, which was allowed to circulate for 14½ hours longer. The details of the cooling are given in the "statement of fabrication" (Table No. 1).

TURNING AND BORING.

When the gun had become thoroughly cooled the flask was removed, and the outside cleaned of as much of the scale as came off readily. The hoisting from the pit was attended with some delay and difficulty, as the foundry cranes were too light for the purpose, and additional hoisting machinery had to be erected temporarily. It was finally accomplished on the twelfth day after casting, and the gun was lowered upon skids alongside the pit. The remainder of the scale was chipped off from the exterior, and the bore was cleaned, as far as practicable, after being treated with a solution of diluted sulphuric acid to soften the scale. The gun was then transferred to the machine shop, and placed in the heading lathe. While in this machine the greater portion of the superfluous metal of the chase was removed by cutting in at short intervals to

within 2 or 3 inches of the required diameter, and then breaking out the intervening rings with chisel and hammer. A ring for testing purposes, 3½ inches thick, was cut next to the muzzle, and, as soon as work upon the chase was sufficiently advanced, was detached, together with the sinking head.

The gun was next transferred to a boring-lathe, where the operations of boring and turning could be carried on at the same time. In this machine the bore was finished for the reception of the tube and the exterior, with the exception of the trunnion section and the extremity of the breech, turned down to the prescribed dimensions.

A careful inspection at this stage of the work showed the bore to be smooth and free from flaws, and no defects of importance were found on the exterior.

Measurements with the star-gauge showed a diameter of bore varying only from 19.494 to 19.496 inches, and the eccentricity nowhere exceeded 0.002 inch.

The straightness of the bore was verified by a cylinder-gauge 60 inches in length and 19.49 inches in diameter, which was inserted to the bottom and withdrawn without difficulty. To finish the trunnion section of the exterior the casing was placed in a trunnion-lathe and the trunnions turned down to their proper dimensions, while the greater part of the excess of metal between was removed by a planing-machine working at the same time. The sight-seat and rimbases were next finished by chipping off the surplus metal by hand and filing down, and an indicator-hole for the gas-escape was bored near the breech.

As soon as the diameter of bore of the casing was determined the tube was placed in a lathe and the exterior finished to a diameter varying uniformly from 19.488 inches near the breech to 19.483 inches in the vicinity of the muzzle, thereby allowing a play between tube and casing varying from 0.007 to 0.013 inches.

The tube now being ready for insertion, the casing was placed in position upon two lathe-beds, with the muzzle slightly elevated. The tube was suspended by slings to a truck-crane, and, having been thoroughly oiled and the breech smeared with red lead, was swung in front of the casing and inserted as far as the slings would permit. These were then shifted forward by changing the position of the crane, and the tube was allowed to slide gradually down until it reached the bottom. No difficulties on account of sticking or binding were encountered. The tube was then withdrawn, and the operation of insertion repeated until by filing the bottom of the tube a thorough contact was secured between it and the bottom of the bore of the casing. After this had been accomplished the tube was placed in the rifling-machine and rifled. It was then finally inserted, and the muzzle-collar, which had been finished in the mean time, was fitted and screwed home.

The gun now being assembled, it was placed in the heading-lathe and the muzzle faced; holes were drilled for the vent-piece and securing-pins, which were inserted in their places.

Finally, the breech-square, which had been left at the breech for handling the gun in the lathe, was turned down until it could be broken off, which was done by blows from a sledge-hammer, and the breech was finished by chipping off the remainder of the surplus metal by hand.

TESTS.

The ring taken from next the muzzle of the gun was tested for initial tension, and specimens were afterwards taken out for ascertaining the tenacity and density of the metal. The results are given in Table No. 1.

The metal of the ring in several places was quite spongy, indicating an insufficient length and weight of sinking-head, and considerable difficulty was experienced on this account in securing suitable specimens for the test. The ring was taken from that part of the casting where the metal was poured in from ladles (and consequently was somewhat cooled). It is not certain, therefore, that the specimens taken from it correctly indicate the physical properties of the metal in the gun which came direct from the furnaces. An outside specimen, taken from the gun 19 inches from the muzzle, was tested, and gave results materially different from specimens taken from the ring. (See Table No. 1.)

INSPECTION.

The inspection made at various times during the progress of the construction showed the workmanship of the gun to be satisfactory throughout.

The gun when finished (December 21, 1877) was sent to the proving-ground at Sandy Hook, N. J., for proof and trial.

Principal dimensions.

Diameter at muzzle	inches	27.55
Diameter at 18 inches from muzzle	do	27.55
Diameter at 38 inches from muzzle	do	27.70
Diameter at 58 inches from muzzle	do	29.38
Diameter at 78 inches from muzzle	do	31.78
Diameter at 98 inches from muzzle	do	34.83
Diameter at 118 inches from muzzle	do	38.48
Diameter at 138 inches from muzzle	do	42.68
Diameter at 158 inches from muzzle	do	47.08
Diameter at 178 inches from muzzle	do	50.93
Diameter at 198 inches from muzzle	do	53.78
Diameter (maximum) at 218 inches from muzzle	do	55
Diameter at breech	do	47.16
Diameter at neck	do	41.60
Diameter of trunnions:		
Right	do	15
Left	do	15
Diameter of rimbases:		
Right	do	17
Left	do	17
Total length of gun	do	262.92
Length of trunnions:		
Right	do	6.31
Left	do	6.32
Distance between rimbases	do	55.09
Distance from axis of trunnions to face of muzzle	do	167.67
Distance from axis of trunnions to rear of breech	do	95.25
Distance of axis of trunnions from axis of bore	do	.005
Total length of tube	do	232.12
Total length of bore of casing	do	232.12
Maximum eccentricity of bore of casing	do	.002
Length of B tube	do	59.86
Depth of wrought-iron cup at bottom of tube	do	5.07
Thickness at bottom of wrought-iron cup	do	5
Diameter of finished tube from bottom to 60 inches	do	19.486 19.488
Diameter of bore of casing from bottom to 60 inches	do	19.494 19.496
Corresponding play	do	.009
Diameter of finished tube from 60 inches from bottom to muzzle	do	19.483 19.486
Diameter of bore of casing from 60 inches from bottom to muzzle	do	19.494 19.496
Corresponding play	do	.013
Length of neck of tube under muzzle-collar	do	6.96

Length of muzzle-collar	inches..	6.96
Length of recess in casing	do....	7.42
Length of screw on muzzle-collar	do....	4.875
Length of screw on recess in casing	do....	4.75
Excess in length of screw on collar over that on recess	do....	.125
Diameter of tube over neck	do....	16.506
Interior diameter of muzzle-collar	do....	16.51
Corresponding play	do....	.004
Diameter of muzzle-collar across threads	do....	19.992
Diameter of recess on casing	do....	19.999
Play between collar and casing	do....	.007
Thickness of collar	do....	1.741
Pitch of thread on collar	do....	.75
Radius of curve at bottom of bore of casing	do....	2.18
Radius of curve at bottom of tube	do....	2.25
Diameter of gas-channel through casing	do....	.23
Distance of interior orifice below axis of bore	do....	7.06
Distance of exterior orifice from tangent to bottom of gun	do....	18.16
Length of bore of A tube	do....	227.11
Length of rifled portion of tube	do....	206.90
Diameter of bore across lands	do....	{ 12.227 12.247
Width of grooves	do....	.916
Width of lands	do....	.9166
Depth of grooves	do....	.091
Pitch of rifling	feet...	70
Diameter of vent	inches..	.2
Diameter of vent-bushing	do....	1
Axis of vent from bottom of bore	do....	9.2
Axis of vent from vertical plane through axis of bore	do....	3.15
Length of securing-pins:		
No. 1	do....	5.06
No. 2	do....	5.55
No. 3	do....	9.52
No. 4	do....	11.68
Diameter of securing-pins:		
No. 1	do....	1.504
No. 2	do....	1.50
No. 3	do....	2
No. 4	do....	2
Distance of securing-pin from muzzle:		
No. 1	do....	28.08
No. 2	do....	48.05
No. 3	do....	105.58
No. 4	do....	128.84
Weight of gun	pounds..	89,350
Counter preponderance	do....	51

Foundry history of the 12.25-inch muzzle-loading rifle, manufactured at the South Boston foundry, Boston, Mass.

CHARGE OF METAL.

Grade of iron.	Furnaces. No. 1.	No. 2.	No. 3.	Total.
IRON USED.	*lbs.*	*lbs.*	*lbs.*	*lbs.*
No. 1	15,000	15,000	15,000	45,000
No. 2	15,000	15,000	15,000	45,000
No. 3 (hard) / No. 3 (soft)	15,000	15,000	15,000	45,000
Remelted	15,800	15,800	15,800	47,400
	60,800	60,800	60,800	182,400
COAL CONSUMED.				
Melting	....	....	....	57,000
Fusion	....	....	....	27,000
	....	....	....	84,000

Character of test-sticks.

	Furnaces.			
	No. 1.	No. 2.	No. 3.	Basin.
Iron	Nearly white	Mottled	Slightly mottled	None taken.

Record of casting.

MAY 30.

Furnaces fired at	3.30 and 4 a. m.
Metal down at	12.30 p. m.
Time of melting	9 hours.
Time in fusion	$4\frac{1}{6}$ hours.
Gun cast at	4.40 p. m.
Time occupied in casting	15 minutes.
Temperature of water entering core-barrel	62 degrees.
Temperature of water leaving core-barrel (45 minutes)	113 degrees.
Rate of water per minute	36 gallons.
Fire kindled in pit	6 o'clock p. m.

MAY 31.

Water shut off at	5 p. m.
Core-barrel removed at	6.45 p. m.
Water entered gun at	6.57 p. m.
Temperature of water entering gun	64 degrees.
Temperature of water leaving gun in 13 minutes	136 degrees.
Total time in cooling gun	$119\frac{1}{2}$ hours.

JUNE 2.

Fire in pit went out	6 a. m.
Fire in pit burned	60 hours.

COOLING TABLES.

Core-barrel.		Core-barrel removed.							
Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.	Hours.	Degrees.
1	110	23	84	45	129	67	87	89	72
2	106	24	83	46	128	68	85	90	72
3	104	25	....	47	127	69	84	91	70
4	102	26	....	48	126	70	83	92	70
5	100	27	185	49	126	71	81	93	70
6	98	28	179	50	125	72	81	94	70
7	100	29	169	51	123	73	81	95	70
8	100	30	159	52	121	74	80	96	70
9	100	31	150	53	119	75	79	97	70
10	100	32	146	54	117	76	78	98	70
11	102	33	139	55	114	77	78	99	70
12	100	34	134	56	110	78	76	100	70
13	100	35	140	57	105	79	76	101	70
14	100	36	142	58	101	80	75	102	70
15	100	37	144	59	99	81	75	103	70
16	99	38	146	60	97	82	75	104	70
17	90	39	143	61	95	83	75	105	70
18	90	40	138	62	93	84	75	106	69
19	89	41	136	63	92	85	74	107	69
20	88	42	134	64	91	86	74	108	69
21	87	43	132	65	89	87	74	109	68
22	86	44	131	66	88	88	74	110	68

MECHANICAL TESTS.

Specimens.	Density.	Tenacity.
No. 6 (outside)*	7.3454	39,900
No. 8 (middle)*	7.2717	33,000
No. 4 (inside)*	7.2731	30,000
No. 3 (outside)†	7.3374	40,794
No. 8 (middle)†	7.2698	34,346
No. 1 (inside)†	7.3155	40,704
Radial specimen‡	7.2728	33,881

* Specimens tested at the United States Ordnance Agency.
† Specimens tested at the foundry.
‡ Specimen taken from outside of gun at about 19 inches from muzzle.

Initial tension.

	Inches.
Exterior diameter of ring	49
Interior diameter of ring	17.75
Thickness of ring	3.54
Thickness of broken sections	0.58
Interior of opening	0.068
Exterior of opening	0.184
Circumference of exterior of ring	153.938
Exterior per inch of circumference	0.001195
Initial tension ... pounds	19,500

REMARKS.—Equal quantities of Dover and Muirkirk were used in charging the furnaces. Record of coal consumed was not kept for the different furnaces. Furnaces Nos. 2 and 3 fired at 3.30, No. 1 at 4 a. m. Cooling tables represent the temperature at which the water left the core-barrel and gun. Temperature was at 68° when the water was shut off.

PRELIMINARY EXPERIMENTS AND TESTS.

Previous to casting the gun-casing a number of experimental castings were made and tested with a view to determine the proper quality of iron to be employed. This course was necessary in order to provide a substitute for the Richmond pig iron, which can no longer be procured of suitable quality for gun construction. The most satisfactory results in these experiments were obtained from a mixture of equal quantities of Dover and Muirkirk pig iron. A trial cylinder of the same form and dimensions as those described in Captain Rodman's Experiments on Metals for Cannon (pp. 225 and 226) was then cast from the mixture. This cylinder was cut up in the same manner as those above referred to, and was subjected to a similar series of tests for the purpose of determining the physical properties of the metal. The results obtained from these tests were satisfactory, and it was decided to use a similar mixture for the gun-casing.

The Dover is made at Chatham, Columbia County, New York, being smelted with charcoal from a brown hematite ore found a few miles south of Dover Plains, Dutchess County, New York. This ore is mined in a wide vein, and is of two kinds, there being two lines of deposit in the stratum. One is a rich, solid ore, yielding from 48 to 55 per cent. of iron; the other yields from 38 to 42 per cent. In smelting the iron the two kinds of ore are used in nearly equal proportions, it having been found that such a mixture gave the best results.

The Muirkirk iron is made with charcoal at Muirkirk, Prince George's County, Maryland. The ore used is a nodular carbonate of iron from the tertiary sands of the western shore of Chesapeake Bay. It is more or less altered into sesquioxide of iron by the action of surface water, and is cleaned and roasted before charging the furnace.

The yield of iron from the raw ore is from 40 to 45 per cent., and from the roasted about 50 per cent.

Both of these irons have been used at the South Boston foundry for a number of years and with excellent results, but have not heretofore been employed for ordnance purposes.

Mean physical properties of trial cylinder.

Density		7.2771
Tenacity	pounds..	33,875
Elastic limit under tensile strain	do....	9,750
Extension under strain at elastic limit	inch..	0.00051
Ultimate extension per inch	do...	0.00337
Ultimate restoration from extension	do ..	0.00199
Permanent set	do...	0.00163
Elastic limit under strain of compression	pounds..	8,200
Compression per inch under strain of elastic limit	inch..	0.00093
Compression per inch at 35,000 pounds	do...	0.00376
Restoration from compression at 35,000 pounds	do...	0.00280
Permanent set from compression at 35,000 pounds	do...	0.000955
Transverse resistance	pounds..	11,556
Tangential resistance per square inch	do....	63,184
Ultimate resistance to crushing force	do....	114,143
Hardness		18
Hardness of copper		4.16

Mean physical properties of English (Redsdale) bar iron employed in manufacture of coiled wrought-iron tube for the 12-inch rifle.

Density		7.6353
Tenacity:		
Along the fiber	pounds..	56,800
Across the fiber and parallel with the depth of the bar	do....	42,000
Across the fiber and perpendicular to the depth of the bar	do....	24,000
Elastic limit under strain of extension	do....	21,333
Extension per inch at elastic limit	inch..	0.0029
Ultimate extension per inch	do...	0.264
Ultimate restoration per inch	do...	0.0025
Ultimate permanent set per inch	do...	0.2030
Hardness		9.717
Hardness of copper		4.16

THE 10-INCH MUZZLE-LOADING RIFLE CONVERTED.—EXPERIMENTAL.

(Plate XLI.)

DESCRIPTION OF THE GUN.

The cast-iron casing C consists of a 13-inch Rodman smooth-bore gun, bored up to a diameter of 17 inches. The tube is of coiled wrought iron, and is inserted and secured in the casing in the same manner as in system No. 1. The inner or A tube is made in two sections. The breech section A′ is joined to the muzzle section A by counterboring and cutting a screw-thread in the latter for its reception. The section A′ is united by shrinkage with the outer or B tube. The latter tube, for a distance of 5 inches from its joint with the muzzle-section of the A tube, is bored to an interior diameter of 13 inches, and for the remainder of its length to 13.5 inches, thereby forming the shoulder *a a* 0.25 inch in height. It extends 2.5 inches beyond the A′ tube at the rear, and the bottom is closed by the disk D, which is screwed in and forms a close contact with the breech of the A′ tube.

The object of this form of construction is to secure an increased longitudinal strength to the system of lining cast-iron guns with coiled wrought-iron tubes. By this arrangement all the longitudinal strength

existing in both the inner or A′ tube and the B tube can be brought into play.

Heretofore the B tube has only been shrunk on without a shoulder, and thus only aiding the inner tube (longitudinally) by the resulting friction, and has not the advantage of the positive locking together of the tube and jacket provided for by this form of construction.

The action in actual practice will be as follows:

On the discharge of the gun, the powder impresses on the bottom of the bore the pressure of its gases, and also on the projectile. The latter in its passage through the bore—especially when the maximum pressure attains—creates considerable and dangerous longitudinal strains from friction on the surface of the bore, calling into play the longitudinal strength of the inner tube, which, ordinarily constructed, has in some cases failed (as experiments have shown) to sustain the strain, and longitudinal rupture has ensued.

By the plan under consideration the screw-cup E, held firmly at the bottom of the bore by the developed gases, transmits the pressure it susains to the disk D, which in turn holds the outer tube or jacket B by its union with it.

The projectile in its passage through the bore throws a powerful (frictional) longitudinal strain on the inner tube, which, when the maximum strains are reached, transmits the thrust to the shoulder *a a*. This in turn transmits it to the jacket B, which being secured at the base by the disk D, is drawn upon for its longitudinal strength in the manner provided for by the improvement presented.

RIFLING AND VENTING.

The gun is rifled with 17 lands and grooves, each of equal width. The full depth of rifling stops at 18 inches from the bottom of the bore, and the grooves are connected with the unrifled portion of the bore by a bevel 1.5 inches in length.

	Inch.
Width of grooves and lands	0.924
Depth of grooves	0.08

Twist uniform, one turn in 50 feet.

The vent is located 2.5 inches from and parallel to a vertical plane through the axis of the bore, and enters 4.5 inches from the bottom.

FABRICATION.

The work of conversion was performed at the South Boston foundry. The gun used for the casing was a 13-inch Rodman smooth-bore, manufactured at the same foundry and inspected and proved in 1866.

The gun was placed in a boring lathe and bored up to 17 inches, the recess for the muzzle-collar was bored and tapped, and the indicator-hole for the gas-escape bored.

The several parts of the tube, as received at the foundry, were bored under size and rough-turned, so as to leave a slight excess of metal above the required diameters. To join these parts, the B tube was bored up to the required diameter, and the thread cut at the breech for the disk. The muzzle section of the A tube was counterbored, threaded, and beveled for the reception of the breech section. The latter section was then finished at the joint, so as to make, as near as practicable, a mechanical fit, while the remainder of the exterior was turned to a diameter to enter the B tube under a shrinkage of about

0.003 inch. The spiral groove for the gas-escape was then cut and the breech squared off and finished.

To shrink the two parts together, the B tube was placed vertically, breech upward, upon the end of a hollow cast-iron cylinder, with an interior diameter large enough to admit of the free passage of the front end of the breech section of the A tube. It (the B tube) was then inclosed in a cylinder of sheet iron and heated up by a wood fire until the interior diameter had expanded 0.06 inch.

The section of the A tube, after being filled with cold water, which was confined in the bore by a wooden plug, was attached to a crane, and lowered into the B tube until the shoulders on each came in contact. A stream of water was then turned upon the B tube, and continued until it was thoroughly cooled. The disk D was then screwed into its place at the breech.

The surface of contact of the joints of the two sections of the tube, as now assembled, were next turned down and fitted to the front section of the A tube, until as close a junction was secured as was practicable. The sections were then screwed together, and the tube turned down in a lathe to the required dimensions for insertion in the casing, and afterwards bored up to the prescribed diameter and rifled.

The mode of inserting the tube was identical with that employed in the construction of the 12.25-inch rifle.

After the insertion of the tube, the vent-piece and securing-pins were inserted in their places, and the muzzle faced. The tube and muzzle-collar were allowed to project 1.5 inches beyond the muzzle of the casing.

8-INCH BREECH-LOADING RIFLE.—EXPERIMENTAL.

(Plates XLII, XLIII, XLIV.)

The board on heavy rifled ordnance, instituted by the War Department under the act of Congress of June 6, 1872, for the selection of breech-loading and muzzle-loading rifled ordnance for experiments and tests, in submitting its recommendations, designated, among others, a Krupp breech-loading system for procurement by the United States, placing it, among breech-loaders, first on the list in order of merit.

The recommendations of the board were only carried out at the time, as far as breech-loading guns were concerned, by the fabrication of the Thompson and Sutcliffe rifles, which latter now await the appropriation of funds by Congress for the prosecution of experiments with them.

The test of a system embodying the round-wedge fermeture (Krupp pattern) as a breech mechanism, was delayed at the time (other systems taking precedence), and the Department was only able, during the last year, to undertake and cause to be fabricated as a conversion an 8-inch breech-loading rifle (with round-wedge fermeture) by the alteration of a 10-inch smooth-bore, and thus practically carry into effect the recommendation of the board on heavy ordnance of 1872 looking to the test of a system of breech-loading regarded by it as promising superior results to all others presented for its consideration and action.

The details of the breech mechanism being well known, the main question was to devise a system of gun construction involving the utilization of a cast-iron gun and combining with it a steel breech-piece inserted at the rear, furnishing a strong and proper support for the breech-block, and providing an aperture to receive and work in it the latter.

The longitudinal weakness (for want of metal) which would evidently attain if we attempted to form an aperture in the breech of a cast-iron gun to receive the breech-fermeture; also the inherent weakness of cast iron to stand the strains and jar of firings; also the material shortening of the bore which would result—conclusively led, with other considerations in the planning of this conversion, to the use of a steel breech-piece extending beyond and to the rear of the cast-iron body, sufficient to receive and work in it a well proportioned and sufficiently strong fermeture.

The important question of solidly uniting the steel receiver of the fermeture with the cast-iron body received attentive consideration. It was decided that a screw-thread of the same form, pitch, and dimensions as that employed in the case of the 8-inch muzzle-loader, breech insertion, would (both from our calculations and the successful results attained with the latter gun) give all the solidity and strength that could possibly be brought into requisition in service.

To insure no possibility of the cast iron rupturing from the longitudinal strains, the screw-thread, it was determined, should be placed upon the front part or jacket portion of the breech-receiver. This extension not only affords a place for the thread, but also gives additional tangential strength to the system by supporting the wrought-iron coiled tube forming the interior lining of the gun. The tube is further tangentially supported by that portion of the breech-receiver rearward of the jacket portion which finds place in the cast-iron body, and extends far enough into the breech to nearly or quite envelop the charge chamber and seat of the shot; thus affording a strength more than adequate to resist the great strains which must be sustained by this portion of the gun. The enlargements (rearward of jacket portion) in diameters of the breech-receiver piece also provide sufficient metal to resist the longitudinal and jarring strains to which the protruding walls of the breech-piece are subjected at the point where it protrudes from the cast-iron body. The protruding portion, it will be seen, is so dimensioned as to accommodate the fermeture, and have all the requisite strength for its functions.

The bore-tube, it was decided, should be made of coiled wrought iron on account of the decided success heretofore attained by us in lining guns with coiled tubes constructed of this metal.

The tube is shouldered to prevent any forward movement of the tube, either from the pressure developed at the seat of the gas-check or the strains resulting from the thrust of the projectile developed by the friction between the walls of the gun and the shot in firing.

A steel band, it was deemed advisable, should be shrunk on to the cast-iron body at its breech end, to give additional tangential strength to the system, and also to give a better finish and appearance to the gun.

SUMMARY.

In this construction, the question of the strength of the system to withstand the different strains which it will be subjected to in service, it is thought, has been fully met. The coiled wrought iron as an interior lining tube secures all the strength and extensibility requisite to withstand the tangential strains developed at the surface of the bore, using the heaviest battering charges for the caliber employed, and the durability of the surface of the bore and the rifling—using expanding systems of projectiles—have been fully proved. The disabilities likely to arise from defective coiled welds are also fully met by shouldering the tube.

The use of a steel breech-piece secures all the necessary strength, in

providing for the reception and working of a practical and thoroughly digested and tested system of breech mechanism, and also essentially and materially adds by its extension into the body of the cast iron—enveloping the wrought-iron tube beyond the space of dangerous pressures—to the tangential strength of the system. The cast-iron body playing a secondary part, as its inferior strength demands, finds its interior surfaces so placed or distanced with reference to the strains developed at and along the bore as to be far within their capacities for endurance, and its thickness of walls gives all the necessary additional strength required to complete the system of construction, save, perhaps, the reinforce afforded by the steel band at the seat of the charge.

The utilization of cast iron, it is believed, will materially diminish the expense of breech-loading cannon of heavy calibers, using the round-wedge fermeture, now so costly in their fabrication, and will enable us to secure, and within the mechanical resources of our own country, desirable and necessary breech-loading armaments of all desirable calibers, for our sea-coast defenses, at moderate outlays, and having all the essential features of durability and strength found in the more expensive system of the same kind now used by most of the principal (continental) powers of Europe.

A full and special description of the gun, as actually made, will be found embodied below in this report.

DESCRIPTION.

Plate XLIII, Fig. 2.—C is the cast iron casing, which consists of a 10-inch Rodman smooth-bore gun, cut off at the breech to a length of 123.25 inches, and bored up to the requisite diameters to receive the tube A with its jacket B, which is inserted at the breech.

The tube is made of coiled wrought iron, and is of equal length with the casing. It is re-enforced at the breech end for a distance of 40 inches by a steel jacket, which is united with it by skrinkage. The breech of the jacket is prolonged 24 inches to the rear of the casing and tube, and is fitted for the reception of the mechanism of the breech-fermeture.

The united tube and jacket are inserted in the casing with a shrinkage 0.006 inch over the jacket, while the tube in front has a play of about the same amount. They are held in position by the thread *a a* and the muzzle-collar *b*, also the shoulders *c c*. The breech of the casing is re-enforced by the steel breech-band D, which is put on under a shrinkage of 0.03 inch, and secured by the pin *h*.

The breech mechanism works in a slot cut in the prolongation of the steel jacket to the rear of the casing and tube, and is in all its essential features the same as that used in the Krupp breech-loading guns of heavy caliber.

The steel breech-block E is constructed on the sliding-wedge system, and is cylindro-prismatic in form. The front face of the block is perpendicular to the axis of the bore, while the rear or cylindrical portion is inclined 1° 15′. The movement is regulated by the two guides *g g* in the slot, which work in corresponding grooves in the block, and are constructed parallel to the axis of its cylindrical portion.

The front of the block is hollowed out for the reception of a hardened disk *c*, called the obturator-plate. This plate, when the breech is closed, abuts against the gas-check *f f*, which consists of a Broadwell ring inserted in a recess at the rear of the tube.

Plate XLIV.—The breech-block is fitted to receive the different pieces of mechanism required for working it. These consist of the locking-

plate *a*, the translating-screw *b*, and the locking-screw *c*, with its nut *d*. The locking-plate is attached by screws to the left side of the breech-block. The translating-screw is located in a longitudinal groove in the upper surface of the block, and is secured in position by bearings at each end. It works in the half nut *e*, which is attached to the breech-receiver by a screw.

The locking-screw and its nut are located in a cylindrical recess at the rear of the block, and next to the locking-plate. The neck of the screw passes through and turns in a hole in the locking-plate, and the opposite end in a recess in the breech-block. The nut is made about one-half an inch shorter than the recess, which allows it a motion of translation along the screw for that distance. At the end of the nut next to the locking-plate is attached a stud, which limits its rotary motion with the screw to one-third of a turn. On the interior surface of the nut are four rings or circular threads; the one next to the locking-plate is complete, while the others are partially sheared off. When the breech is nearly closed the sheared threads lock into the indentations *g g g*, and the complete one enters the recess *f*. In withdrawing the block the sheared portion of the nut is brought to the rear.

The two screws are worked in turn by the lever-wrench C.

To close the breech the wrench is placed upon the head of the translating-screw, and the block run until the uncut thread of the locking-nut comes to a bearing in its recess and brings the movement to a stop. The wrench is then shifted to the locking-screw; for one-third of a turn the screw and nut turn together, and the partially sheared threads of the nut lock into their corresponding recesses on the breech-receiver. The movement of the nut is then stopped by its stud, while the movement of the screw continues, and bringing the threads of the nut to a firm bearing on the faces of their recesses on the breech-receiver, forces the block into the slot until it is firmly wedged, and the breech thus fully closed.

To open the breech the locking-screw is turned in the opposite direction, and by carrying the nut with it for one-third of a turn the unlocking is effected. The nut is brought to a stop by the stud as before, the uncut thread comes to a bearing against the face of its recess, and the block is drawn out until the nut is reached by the end of the screw. The remainder of the movement is then effected by the translating-screw.

The outward movement of the block is limited by the chain *h* (Plate XLIII, Fig. 3).

Plate XLII shows side elevation of gun (breech closed ready for firing) and plan of gun (breech open ready for loading).

RIFLING, CHAMBERING, AND VENTING.

The gun is rifled with fifteen lands and grooves, each of equal width. The lands are connected with the chamber by a bevel 1.5 inches in length.

	Inch.
Depth of rifling	0.075
Width of lands and grooves	0.83776

Twist uniform, one turn in 40 feet.

The chamber is 22 inches in length, and equal in diameter to the bore across the grooves. It has a capacity for a maximum charge of 35 pounds of powder.

The vent is located in the breech-block, in such a position as to be in the axis of the bore when the breech is closed.

FABRICATION.

The work of conversion was performed at the South Boston foundry. The gun selected for the casing was a 10-inch Rodman smooth-bore gun, No. 11, made at the same foundry, and inspected and proved in 1864.

The density and tenacity of the metal were as follows:

Density	7.245
Tenacity ...pounds..	34,359

The wrought-iron tube was manufactured at the West Point foundry, from Ulster tube iron, 4 by 3.35 inches. It was made in four sections, which were butt-welded together by the process usually employed at that foundry, then bored to 8 inches, turned to an exterior diameter slightly in excess of that required, and subjected to a water test of 120 pounds to the square inch.

Specimens of the iron used were tested with the following results:

Density	7.6550
Tenacity ...pounds..	48,010

The jacket, breech-block, and breech-band were manufactured at the works of Sir Joseph Whitworth & Co., at Manchester, England, and are made of "fluid compressed steel."

This metal is subjected, while in a liquid state, to a heavy pressure, for the purpose of expelling air-bubbles, and is afterwards reheated and hammered to secure uniformity and regularity of structure. Thorough tests of the physical properties of this metal were made from specimens supplied from Whitworth's works, together with others taken from the jacket.

To prepare the casing for the reception of the tube and jacket, it was bored up to 11 inches, recessed for the muzzle-collar, and cut off at the breech to the required length. It was then counter-bored from the breech to the following diameters, viz: For 56 inches to 12 inches; for 40 inches to 16 inches; for 18 inches to 16.825 inches; for 13.5 inches to 20 inches; for 3.5 inches to 22 inches.

The end of each counter-bore was rounded off to form a suitable shoulder, and a thread for the jacket, 0.4 inch depth, was cut upon the 16-inch diameter. The exterior was then turned down at the breech for putting on the steel breech-band.

The interior of the jacket was bored up to the required diameters, and the slot for the breech mechanism drilled out and finished by boring and planing. The tube meanwhile was chambered, rifled, recessed for the gas-check, and the exterior turned down at the breech end to an average diameter of 0.003 inch in excess of that of the interior of the jacket. The jacket and tube were then shrunk together by heating up the jacket until the interior was sufficiently expanded to receive the tube, which was lowered in by means of a crane.

The exterior of the jacketed tube was next turned down to the diameter given in table No. 2.

In order to provide for the longitudinal expansion of the casing, which would take place in heating it up for the insertion of the jacketed tube, the shoulders upon the jacket were finished so as to allow a clearance large enough to obviate any danger of contact with the casing before a bearing was effected at the shoulder on the wrought-iron tube. The screw-thread was turned with a clearance of 0.02 inch on the outer surface, and 0.12 inch on the surface opposite the one of contact with the casing.

The breech-block, with the attachments, was finished in the mean time, and fitted into the slot prepared for its reception.

The breech-band was bored, turned, and made ready for shrinking on to the casing.

INSERTION OF THE TUBE, ETC.

The casing, jacketed tube, and breech-band, being ready for uniting by shrinkage, one of the pits used in the casting of heavy guns was arranged for heating the casing by placing four furnaces, with a capacity of about 400 pounds of coal each, at equal intervals around the wall. These furnaces rested on cast-iron pillars, which raised them about four feet from the bottom.

Two flues were provided for furnishing air to the furnaces, one on either side of the pit, with branches at the bottom so that the air could be delivered directly under the furnace-grates, while near the top of the pit an opening was made and connected with a chimney and a damper inserted in the opening, by means of which the draught could be regulated.

To form a support for the casing, two sections of gun-flask were placed one above the other in the center of the pit, and the upper one covered with a thick cast-iron plate; upon this plate a hollow cast-iron cylinder of suitable dimensions was placed to form a rest for the muzzle of the casing. The casing was placed breech upward in the pit, the muzzle resting on the cylinder, and was securely braced at the trunnions.

In this position, the breech of the casing was almost flush with the top of the pit, which was covered with a large plate of boiler iron. In the center of this plate was a circular hole for the insertion of the tube.

A moderate fire was kindled in the furnaces about 48 hours before the contemplated time of insertion, for the purpose of drying the pit, which had become quite damp from long disuse. About 40 hours after kindling, the fires were replenished to the full capacity of the furnaces.

The jacketed tube, meanwhile, was prepared for insertion. Water caps were fitted into both ends of the wrought-iron tube. The one inserted at the breach was provided with inlet and outlet pipes for attaching hose, for the purpose of turning on a current of cold water in case that a withdrawal should become necessary. A cast-iron "spider" or ring with handspike sockets on the exterior, was secured to the breech of the jacket, for screwing it into the casing.

The temperature of the casing was taken at various intervals, and the diameter of its bore measured. About half an hour before the insertion was attempted the temperature was found to be 633°, while the maximum diameter of the bore had increased from 22.005 inches to 22.09 inches. The length of the casing from the breech to the forward shoulder in the bore was found at the same time to have increased from 55.98 inches to 56.22 inches.

The diametrical expansion of the casing now being considered sufficient to effect the insertion of the tube, the latter, filled with cold water, was lowered by a crane into the bore of the casing until the threads came in contact. Handspikes were then placed in the sockets of the "spider," and the tube rapidly screwed home. The entire operation of insertion was accomplished without difficulty, and occupied only eight minutes.

The covers were now removed from the pit, the fires in the furnaces extinguished, and a stream of water was turned upon the gun to hasten the cooling. When it had returned to nearly its normal temperature the breech-band was inclosed in a sheet-iron cylinder and heated by a

wood fire until its diameter had increased about 0.06 inch. It was then raised with a crane by means of hooks, which clasped its forward end, swung round until directly over the gun, and lowered to its place upon the breech of the casing. It was then cooled by a stream of water, and a hole was bored for the securing-pin, which was inserted in its place.

The gun was then removed from the pit, the muzzle-collar was fitted and screwed home, and the muzzle faced and finished in a lathe.

This substantially completed the fabrication of the gun.

PRINCIPAL DIMENSIONS.

Total length of gun	inches	147.25
Length of cast-iron casing	do	123.25
Length of wrought-iron tube	do	123.25
Length of steel jacket	do	64
Length of breech-band	do	15
Exterior diameter of breech-band:		
Maximum	do	35.70
Minimum	do	35.05
Interior diameter of breech-band	do	30.97
Exterior diameter of casing under breech-band	do	30.99
Length of neck of tube	do	5.50
Length of muzzle-collar	do	5.50
Diameter of neck of tube	do	9.94
Interior diameter for muzzle-collar	do	9.948
Length of recess for muzzle-collar	do	6
Diameter of recess for muzzle-collar	do	11.765
Diameter of muzzle-collar across threads	do	11.755
Length of rifled portion of bore, including bevel	do	101.25
Length of chamber	do	22
Diameter of bore across lands	do	8.00
Diameter of chamber	do	8.15
Width of lands	do	0.83776
Width of grooves	do	0.83776
Depth of rifling	do	0.075
Twist of rifling, one turn in	feet	40
Length of breech-block	inches	23.5
Width of breech-block	do	10
Thickness through center	do	13.5
Width of slot for breech-block	do	10.05
Length of translating screw	do	25.5
Diameter of translating screw across threads	do	1.5
Length of locking screw	do	10.7
Diameter across threads	do	2.75
Length of locking nut	do	5.75
Diameter across uncut thread	do	5.75
Weight of gun	pounds	17,075
Preponderance	do	420

THE 3.5-INCH BRONZE RIFLED FIELD GUN, DEAN'S PATENT.

(Plates XLV, XLVI, XLVII, XLVIII.)

This gun is constructed on the plan of the 3.5-inch Rodman muzzle-loading rifle, model 1870. It is without preponderance. Its length and weight are very nearly the same as those of the light 12-pounder, and it is adapted to the same carriage. The main peculiarity in its construction consists in the application of Mr. Dean's patent process for condensing and hardening the metal of the bore.

FABRICATION.

The gun was cast in a cast-iron flask or "chill" about 3½ inches thick, the interior surface being covered with a slight coating of clay and

sand. It was found necessary to make two castings, as the first one proved defective. The metal used, consisted of three old bronze 6-pounders, furnished by the Ordnance Department, and a part of a bronze 12-pounder on hand at the foundry. At the second casting, the metal of the rejected piece was returned to the furnace, with the exception of a section reserved for tests; and another part of the 12-pounder was added to supply the deficiency. The weight of the charge of metal was 3,364 pounds; the time of melting, one hour and fifty minutes; and time of fusion, one hour and ten minutes. The gun was removed from the flask 18 hours after casting, and when thoroughly cooled, placed in the lathe and the sinking-head cut off. It was next bored out in a boring-machine to a diameter of 3.37 inches.

To condense the metal of the bore, the gun was inclosed in the iron flask in which it was cast, and placed in the condensing machine and firmly secured by heavy iron rods. Six mandrels, varying in diameter from 3.42 inches to 3.50 inches, were used in the operations. These, by means of a hydraulic press of 10-inch bore, were, in the order of their size, successively forced down the bore of the piece and withdrawn; and the operation was repeated until the most of the resilience of the metal had been overcome and the bore enlarged to very nearly 3.50 inches in diameter. The pressures used varied from 500 to 2,400 pounds per square inch, making a total pressure of from 19½ to 94 tons.

After condensing the bore, the gun was removed to the rifling machine and rifled, the grooves being planed out to a little less than the required depth. It was then put back in the condensing machine, and the bore still further enlarged by means of an expanding mandrel so constructed as to follow the opposite lands and grooves.

On account of a slight error in the width of the rifling tool, the grooves were left too narrow for the rib of the mandrel, and consequently the edges of the lands were slightly abraded in the operation. A little grinding with fine emery removed much of the rough edge left upon the lands, but did not wholly restore the smoothness desired.

In this connection, it should be stated that the condensing process was only applied to the cylindrical portion of the bore, and consequently the metal at the bottom was left in its ordinary condition.

The gun was next turned down in lathes to its prescribed exterior dimensions, and a copper vent-piece inserted.

TESTS.

Two specimens, one from the outside and one from near the center, were taken from the sinking-head next to the muzzle, and tested for tenacity and density, with the following results:

	Tenacity.	Density.
Outside specimen	48,230	8.6663
Inside specimen	34,706	8.5651

To test the effect of the condensing process upon the physical properties of the metal a section taken from the first casting was bored out and condensed in the same manner as the bore of the gun. A ring was then cut off and turned down to 0.133 inch in thickness, and tested for density. For hardness, two specimens were tested, one taken from the hardened bore, and one from the outside. A specimen for tenacity, taken from the hardened portion, was also tested.

The following results were obtained:

Density of ring	8.7065
Hardness of unhardened specimen	1.4049
Hardness of condensed specimen	5.1158
Tenacity of condensed specimen	51,571

The comparisons for hardnesss are with wrought copper as 1. An inside specimen, uncondensed, from the same block, gave the following results:

Density	8.3512
Tenacity ... pounds..	35,810

EXAMINATION AND PRESERVATION OF GUNS.

The bore should be thoroughly cleaned, as it is not possible to detect small defects, which may sometimes be of importance, if the bore be in a rusty or very greasy state. If care has been previously taken in keeping a gun tolerably clean, it will probably be sufficiently prepared for examination by washing, brushing, and drying with tow, or a clean sponge-head. If, however, there be hard rust which will not yield, or a thick coating of lacquer or grease, the bore may be cleaned either by firing, if circumstances admit, one or two scaling charges, about one-third the full service charge, without projectiles, which will usually loosen the scale, or by the use of hot water and potash, in the following manner: About a gallon of boiling water is poured on one pound of black American potash, and an old sponge covered with a canvas cap, or some substitute, to make it tight to the bore, is dipped into the solution. The bore is then rubbed till the dirt is loose, when the hard brush will remove it; it is then wiped dry with tow, &c., and slightly oiled. The potash water must be used very hot, and the sponge must be very tight, or the process is ineffectual. No sharp-edged or pointed scrapers should be employed for cleaning the bores of rifled guns; they are unnecessary and liable to injure the rifling.

The bore being thus cleaned should be examined by aid of the reflected sun-rays from a mirror, or in cloudy weather by lamp or candle; if the surface is slightly wet, the detection of defects by this means is greatly facilitated.

The extent and position of any flaw is determined by interior impressions taken with gutta-percha or other suitable plastic substance.

The importance of a defect depends, in a great measure, on its position in the gun; one in the rear of the trunnions, and still more in the powder chamber, being more dangerous than one of the same nature and extent in front of the trunnions, as the powder gas acts much more rapidly upon it, and it is liable moreover in muzzle-loading guns to hold a piece of ignited serge.

In case of doubt as to serviceability of a gun exhibiting defects, an impression should be taken, a few rounds fired, and a new impression taken; if on comparing the impressions no development of the defect is observed, the gun may be considered serviceable.

The effect of service on a vent is seen either by a gradual increase to the channel of the vent itself, by an irregular wearing away of the bottom by the metal of the vent setting up and the gas forming a hollow ring around it, or by fissures or hair lines radiating into the metal of the bore from the edge of the vent bushing, the extent of which can be determined by an impression; if an enlargement to .5 inch on the interior is shown or the exterior enlargement to .25 inch is observed, the gun should be re-vented. In case of decided erosion along the junction of

the vent piece and wall of the gun, exceeding one-tenth of an inch in depth or width, the bushing should be removed and a larger one substituted or the vent aperture should be solidly closed and the gun re-vented in a new place.

PRESERVATION OF RIFLED BREECH-LOADING GUNS.

The bores of such guns will in future be lacquered with black-lead lacquer, composed of—

	Pounds.	Ounces.
Black, lamp, dry	0	12
Lead { black, dry	24	8
Lead { red, dry	6	12
Oil, linseed, raw	9	0

The breech screw and bright parts about the guns will be coated with a composition of tallow, 3 parts; oil, lard, 1 part; lead, white, about one pound to a gallon; the parts which can be removed being laid up in store. Muzzle and breech plugs will therefore be no longer required for these guns.

The lacquer above described can be removed in a few minutes by brushing the bore with hot potash solution.*

SKIDDING OF ORDNANCE.

Cannon should be placed together, according to kind and calibers, on skids of stone, iron, or wood. Permanent skids, made by building small square pillars of brick, about 18 inches high, with old railroad rails laid on top of them, end to end, are best and cheapest. The ground selected should be hard, well rammed, and covered with a layer of cinders or other suitable material to prevent vegetation.

Guns and long howitzers.—The pieces should rest on the skids in front of the base ring and in rear of the muzzle; the axis inclined at an angle of 4 or 5 degrees with the horizon, the muzzle lowest; the trunnions touching each other; or, if space be wanting for that arrangement, the trunnion of one piece may rest on the adjoining piece so that the axis of the trunnions is inclined about 45° with a horizontal line, the muzzle closed with a tompion or a plug of dry wood well saturated with oil or grease; the vent down, stopped with a greased wooden plug or with putty or tallow. If circumstances require it, the pieces may be piled in two tiers, with skidding placed between them, exactly over those which rest on the ground, the muzzles of both tiers in the same direction and their axes preserving the same inclination.

Short howitzers and mortars.—On thick planks or good flagging, standing on their muzzles; the trunnions touching; the vents stopped.

Iron ordnance should be covered on the exterior with a lacquer impervious to water; the bore and the vent should be greased with a mixture of *oil* and *tallow*, or of *tallow* and *beeswax* melted together and boiled to expel the water. The lacquer should be renewed as often as required, and the grease at least once every year. The lacquer and grease should be applied in hot weather. The cannon should be frequently inspected, to see that moisture does not collect in the bore.

* Extracted from English text-book on rifled ordnance.

MECHANICAL TESTS.

*The testing machine** affords the means of relatively determining those properties of metals on which the endurance of guns is believed mainly to depend.

As yet, however, no standard of properties has been determined, nor is it believed to be practicable to fix such standard except by connecting the mechanical tests of a metal with the endurance under the powder-proof of the guns made from it.

The Rodman testing machine.—This instrument is used to determine the capacity of any metal to resist a *tensile*, *transverse*, *torsional*, or *crushing* force. It is also used to obtain the indenting force, and an internal force can be applied for bursting hollow cylinders.

Power exerted.—By a combination of levers and cog-wheels, the action of the power employed is greatly augmented and transmitted to the specimen under trial. The machine consists essentially of a system of three levers, A C, A′ C′, and A″ C″ (Plate XLIX).

The position of the fulcrum in each of these cases is denoted by F′ F′ and F″, respectively. The power is applied at P, and the position of the weights is denoted by W. The levers are connected by rigid rods.

The mechanical advantage of the levers A C is 10 to 1; that of A′ C′ is 20 to 1, and that of A″ C″ is 10 to 1.

We have, therefore, by the formula for compound levers,

$$\frac{W}{P} = \frac{10}{1} \times \frac{20}{1} \times \frac{10}{1} = 2000$$

Explanation of the Rodman machine.—The middle lever, so called because it is intermediate between the other two, is the upper lever A′ F′ (Plate XLIX). All its bearing knife-edge pivots are in the same horizontal plane. Its fulcrum, F′, is supported by an interior frame which is attached to the screw D, above it. The knife-edge A′ connecting by means of a long vertical rod A′ C, with the *small lever* A F, is 97 inches from the fulcrum, F′, and the knife-edge C′ connecting, by means of a strap A″ C′, with the main lever A″ F″, is four inches and eighty-five hundredths from the fulcrum F′, making a proportion between the two arms of the lever as 20 to 1.

The main lever, A″ F″, is the one which acts directly upon the specimen under trial, and is acted upon by the middle lever through a long iron strap A″ C′, which connects them. All its knife-edges are in the same plane. Its fulcrum, F″, is supported by a pair of heavy iron stanchions, B B, fitted to the bed-piece, E E. The knife-edge A″, which is linked with the middle lever, is 90 inches from the fulcrum, F″, and the knife-edge C″, which acts upon the specimen under trial, is nine inches from the fulcrum F″, making the power of this lever as 10 to 1.

The small lever A F, is the one to which the weights are attached. All its bearing knife-edge pivots are in the same plane. Its fulcrum, F, is supported by the lower end of the guide G G′, attached to the main lever stanchions. The knife-edge C, connecting with the middle lever, is two and twenty-five hundredths inches from the fulcrum F, and the knife-edge A, to which the weights are attached, is 22.5 inches from the fulcrum F, making the power of this lever as 10 to 1.

The combination of levers.—A combination of the small lever with the middle lever gives a proportion of 200 to 1; and a combination of all

*Reports of Experiments, &c., by Officer of the Ordnance Department, Cooke's Naval Ordnance and Gunnery.

three of the lever gives a proportion of 2000 to 1. A weight of one pound, therefore, applied to the platforms of the suspending rod T, on the same lever, exerts a force of 200 pounds on the straps A″ C′, connecting with the main lever, and of 2000 pounds at C″, where the strain acts upon the sample.

Capacity of the machine.—The weights used are of two denominations, viz, half-pounds and five pounds, representing respectively 1,000 and 10,000 pounds. Smaller increments of strain than 1,000 pounds are noted on the small lever, which is provided with a sliding weight, and graduated from zero to ten, each number representing an additional hundred pounds.

Of the first denomination there are ten weights, representing a strain of 10,000 pounds, and of the second there are nine weights, representing a strain of 90,000 pounds.

The aggregate strains of all the weights, or the capacity of the machine, being 100,000 pounds.

The cog-wheel gearing.—The large vertical frame E H at one end of the machine (Plate XLIX) supports the cog-wheel gearing, which is set in motion by a crank.

To the heavy main lever stanchions B B a guide, G C, is attached, through the upper end of which the small end G′ of the middle lever passes. This guide ascends and descends evenly with the screw D and the fulcrum F′ of the lever, by means of a rack and pinion, L″ L″, at each end of the revolving rod L. A mortise through the guide receives the lever and allows it a free motion to a limited extent.

The lever is thus maintained in a position always nearly horizontal, while it remains free to oscillate on its fulcrum in either direction, as the strain or the weights may preponderate. The supports of the small lever are attached to the guide G G′, so that it ascends or descends with the middle lever.

Multiplication of power.—Fifty turns of the hand crank I give one turn to the horizontal wheel M, at the top of the frame E.

A screw nut is cut in the axis of this wheel, through which the vertical screw D passes. This wheel, when turned, elevates or depresses the screw and sets in motion all the movable parts of the machine.

Two turns of the horizontal wheel move the vertical screw one inch, and this requires one hundred turns of the hand crank, and gives one-tenth of an inch of motion to the knife-edge of the main lever, where the strain on the sample is exerted.

The crank to which the power is first communicated moves a distance of 72 inches at each turn and 7,200 inches for each tenth of an inch of motion at the straining point of the machine; such a great power is needed only when heavy strains are exerted.

When beginning a strain, or when lowering down the levers, the small pinion O on the crank shaft is thrown out of gear by lifting the latch N and shifting the shaft, thus bringing into action the large pinion R, which change of gearing gives a velocity nine times as great to all the movable parts of the machine, but the force exerted will be only one-ninth as great as before.

The torsion lever L′ works between two heavy pillow blocks, B′, fitted on the bed-frame E, and within these pillow blocks the journals of the torsion lever revolve. Its axle has a cylindrical aperture concentric with its axis. This lever is set in motion by a chain, S, which connects directly with the middle lever through the strap S′.

Pedestals for transverse strains.—Two hollow movable pedestals, T T, are attached to the bed-frame E, fitted with steel knife-edges, which

serve as points of support for the test bars. Horizontal braces secure the stability of the framework of the machine.

Working the machine.—Adjustments: All the working knife-edges, and the seats on which they bear, are made of hardened cast steel; the other principal parts of cast iron.

Before beginning a test it is necessary to see that all the knife-edges are properly adjusted, and that the vertical screw through the horizontal wheel on the top of the machine is run down its full length, to obtain all its scope.

To adjust the equilibrium, there is a small horizontal rod, R′, with a weight working upon it, which is attached to the upper end of the slide, G, G′, supporting the small lever.

Before the specimen is secured in its place the machine must be accurately balanced by moving the weight, W′, of the adjusting rod, either in or out, as it may require. The final and accurate adjustment is made with the small brass weight, W″, attached to the end of the small lever.

The sample holders, in all forms of strains, excepting that of torsion, are attached at one end to a stirrup, C″, on the main lever, and at the other, to the bed-frame. *To apply the strain* to the specimen the hand-crank, I, is turned with regularity in the direction which raises the screw and sets in motion all the movable parts of the instrument.

The slide on the small lever, S″, is moved gradually, just keeping its equipoise; as the strain is increased weights are supplied at P, in such manner as will keep the lever evenly balanced, so that the force applied at the instant of breaking may be accurately determined by counting the weights then on the platforms.

Tensile strain.—After the density of a specimen has been ascertained, and before it is inserted in the holders, its smallest diameter is accurately measured and recorded. This is done by sliding-calipers, an instrument provided with a vernier, which measures hundredths of an inch, and thousandths of an inch may be readily determined by a practiced eye.

The specimen is now fitted between the holders used for the purpose, one of which is attached to the shackle hung on the stirrup of the main lever; the screw, U, connecting with the bed-frame, is then run up by the handles, H′, underneath, until the specimen can be caught between the holders that fit on its upper end.

After the sample is secured between the holders the screw is run down until a sufficient strain is obtained to keep them in place. Then proceed with the test.

The breaking weight is divided by the area of the smallest diameter of the specimen, and the quotient gives the tenacity, or the strength per square inch. That is, let a represent the breaking weight, b the area, and x the tenacity per square inch—

$$b: 1 \text{ square inch} = a : x$$

The following table contains the area and the logarithms for all the variations of diameter likely to occur in tensile samples.

Transverse strain.—For determining the transverse strength of metals a specimen bar is taken, 2 or 3 feet long, and about 2 inches square. It is prepared for the test with a slight dressing with the file or grindstone on one of its faces near each end, in order that the bar may bear more evenly against the supports when under the strain. The middle of the bar—the part where the fracture occurs—is dressed in like manner on each of its four faces, in order that its breadth and depth in this part may be accurately measured.

To place the bar.—Run the screw, U, down nearly level with the bed-frame, out of the way; slide the pedestals to the proper distance on either side, to accommodate the length of the specimen. Suspend the long link, S (Plate XLIX), from the same shackle used in the tensile strain, and pass the bar through the pedestals and the long link, so that it rests in the middle of its length on the knife-edge in the bottom of the link. The latter is then drawn upward until the ends of the bar bear firmly against the knife-edge supports in the pedestals, which must be at equal distances from the link.

The deflection.—The breaking force is applied on the under side of the bar, in the middle, and forces it upwards against the supports at the ends. The deflection is measured by inserting a graduated, tapered metallic scale between the upper surface of the bed-frame and the under side of the bar-holder, directly beneath the forcing-line of the latter, against the center of the bar. The space enlarges as the bar bends, and the graduated wedge measures minutely the deflection of the bar at any stage of its progress.

A record is kept of the "deflection" and *set*, which shows the quantity of deflection and permanent set under a given pressure, which is designed to be near to, but somewhat less than, the minimum breaking weight. Also of the "last deflection," which gives the amount of deflection under the pressure of the breaking weight.

The unit of strength represents the weight in pounds required to break a bar 1 inch square, rigidly supported at one end; the weight being applied at a distance of 1 inch from the point of support. For square bars it is determined by the formula—

$$\frac{l\,W}{4\,bd^2} = S \text{ the unit of strength.}$$

l = the length between the supports.
W = the breaking weight.
b = the breadth of the bar.
d = the depth of the bar.

The breadth and depth are accurately measured near the fracture; and, as the dimensions are irregular, it is proper to measure in three places for each; one measure to be taken in the middle of the bar, and the other two near the corners. The mean of the three measures to be taken as the true dimension. If the bar is defective, the results cannot, of course, be relied on.

Torsional strain.—For determining the torsional strain, or the weight required to break by twisting, a specimen bar is used, which is long enough to project beyond the journals of the torsion lever, and receive the indices, e', which are attached to its ends, a. The parts against which the holding-keys, K′, are pressed are made square. All the other parts are round.

The parts between the keys are dressed to a true cylinder, the length of which should not be less than three diameters. This length is necessary to allow a full development of the fracture to occur within the dressed part of the specimen. The distance between the keys is nineteen inches.

To place the specimen.—The bar passes through the axle of the torsion-lever. One end is held firmly to the pillow-block of the bed-frame, and the other to the journal of the torsion-lever, L′, by means of keys, K′. The axis of the bar is made to coincide with the axis of the torsion-lever, by passing its ends through concentric rings, r, inserted in recesses provided for the purpose, before the keys are fixed in their places. In-

dices, c', are attached to the projecting ends of the bar and adjusted to the zero of the arc beneath, before the strain is commenced.

The diameter of the specimen is carefully measured before it is secured in the journal. Bring the keys up on the bottom, until the bar rests firmly upon them, then key up from the top to keep it firmly in its place. Connect the chain on the torsion-lever to the strap communicating with the middle lever, and proceed with the test.

When a bar is in the machine for torsion, the lever, L′, is placed at its lowest point; but sometimes the screw, D, ascends to its highest limit before the bar breaks. When this happens the lever is propped up, the chain is detached and shortened by removing its upper link; then, on its being again attached, the work is resumed and the strain extended until the bar breaks.

Recording the strain.—In torsional strains the main lever of the testing-machine is inoperative. The recorded breaking weight then is only two hundred times greater than the actual weights on the platforms, which is equal to one-tenth of the usual reading in other tests. But as the torsion lever is 30 inches long from its axis to the point where the center of the chain acts upon it, the weight, as above ascertained, is multiplied by 30, and the product represents the strain exerted at a point 1 inch from the axis of the strained bar. In practice, it is found more convenient to read off the weights for torsion in the same manner as in other tests, and to multiply that reading by three.

The deflection.—Although one end of the bar is firmly fixed it will yield a little by its compression on the keys, and therefore its angular deflection is determined by the difference between the reading on the arcs.

The deflection of the bar is noted at each addition of a certain number of pounds of pressure; and at each addition of, say, 500 or 1,000 pounds, the bar is released from strain and the permanent set ascertained. The greatest angle of deflection and the breaking weight are also recorded.

The torsional strength is—

$$S = \frac{W\,r}{d^3},$$

in which

W = breaking weight.
r = radius of torsion lever.
d = diameter of specimen.

Crushing force.—The samples submitted to the test of compression are small cylinders, the lengths of which are generally two and a half times their diameters. Bars of greater length than these diameters are liable to bend under the pressure before the fracture occurs; and, if the lengths be less than two diameters, the fracture in its regular form may not be fully developed, and a portion of the sample may be pulverized or reduced to small grains. The ends of each sample are made perfectly parallel and perpendicular to the axis, so that all parts of the sample will be equally pressed.

Placing the specimen.—Plate XLIX shows the form of the stirrup used in holding the instrument for *crushing*, *bursting*, and *indenting* samples when the straining force is applied. S is a stirrup, attached at its upper end to the straining stirrup C″ on the main lever; and R is attached to the bed-frame by means of the screw U. V is a block of iron, upon which the sample may rest. The samples or the instrument for holding them are inserted in the space T.

Recording the compression.—The dimensions of the sample are carefully measured before placing it. The depression or permanent set at every 5,000 pounds, for instance, are then carefully noted. The breaking weight is recorded, as well as the angle of fracture of the specimen. The strength per square inch will be—

$$S = \frac{\text{weight}}{\text{area}}.$$

Indenting force.—The comparative softness or hardness of metal is determined by the bulk of the cavities or indentations made by equal pressure; the softness being as the bulk directly, and the hardness as the bulk inversely.

Indenting tool.—Of the different forms of cavity made by indenting tools that of the pyramid is preferred, because of its simplicity and the ease with which its volume may be computed.

The indenting part of the tool is in the form of a pyramid, having a rhombus for its base, the diagonals of which are, respectively, one inch and two-tenths of an inch, the height of the pyramid one-tenth of an inch.

In late experiments the form of the pyramid has been changed and improved somewhat by causing it to make a longer line and mark minute differences more accurately.

Standard of comparison.—The volume of an indentation made with this tool is taken as the measure of the work required to produce it, and is inversely proportional to the hardness of the specimen, that is (denoting by H the hardness of any specimen)

$$H = \frac{k}{v}, \quad \text{.........................} \quad (1).$$

k denoting any convenient constant and v the volume of the indentation corresponding to H.

It has been found by experiment that a pressure of 10,000 pounds on the base of the pyramid makes an indentation in the softest metals used in guns about nine-tenths of an inch long.

The maximum indentation, one inch in length, of the instrument is therefore assumed as the unit of hardness; therefore denoting by V the volume corresponding to an indentation one inch in length, we obtain from equation (1)

$$1 = \frac{k}{v} \text{ or } K = V;$$

and, in general,

$$H = \frac{V}{v};$$

or, putting l = the number of tenths of an inch in the length of any given indentation,

$$H = \frac{V}{v} = \frac{1000}{l^3};$$

since pyramids are to each other as the cubes of any similar dimensions.

A pressure of less than 10,000 will probably be found better suited to the purpose with the improved tools. A better standard of comparison may be found in some metal of uniform density and hardness, easily obtainable in all places.

The silver coin of the country best fulfils these conditions. The volume of the cavity made in this, by the adopted unit of pressure, may be assumed as the unit of hardness; and this divided by the volume of the cavity in any sample tested will denote the hardness of that sample as compared with that of silver coin.*

* Rodman.

Errors of the Rodman machine.—The errors incidental to the use of this machine are due to three causes:

1st. Weight of its different movable parts.

2d. Motion of the centers of gravity of the levers towards or from their fulcrums.

3d. Friction.

The first cause of error is avoided in practice by means of the adjusting weights already described.

The system is brought into perfect equilibrium, so that any increase of W will be balanced by a proportionate increase of P.

The second cause of error is comparatively unimportant, because the levers A C and A′ C′ are so adjusted as never to make a large angle with a horizontal line passing through the fulcrum, and in the case of the lever A″ C″, which makes a larger angle, the shape is such as to bring the center of gravity very near the center of motion.

Let D denote the distance through which the center of gravity moves; *a* denote the distance of the center of gravity from the center of motion; L denote the angle described by the lever during the breaking of a specimen.

In general the levers are so adjusted that the line connecting the centers of gravity and of motion is horizontal when the movement of the lever is half completed.

$$\therefore D = a \text{ versine } \tfrac{1}{2} L.$$

It is evident that one or both of these factors is very small in each case.

The third cause of error is made as small as possible by the use of knife-edges and steel-plates, and is practically inconsiderable.

The determination of the absolute breaking and other strains involve the elimination of errors due to friction, &c., but for obtaining the comparative strength of specimens, the machine is all that can be desired.

MEASURING INSTRUMENTS USED WITH TESTING MACHINE.

(Plate L.)

Sliding calipers.

For outside diameters.—This instrument is used for measuring the specimens of metal to be tested. Its sliding scale is divided into twentieths of an inch. A vernier is attached containing fifty divisions, which cover forty-nine divisions on the sliding scale, and it reads thousandths of an inch. It will measure any space not exceeding two and a half inches, giving the result to the nearest one-thousandths of an inch. The accuracy of its adjustment may be readily verified by pressing the points together gently, and noting whether the zero points coincide. If from the wearing of the steel points, or from other cause, the adjustment should become incorrect, it may be readjusted by turning the screw which forms one of the points.

For outside and inside diameters.—In this instrument the vernier is on the slide, which is moved along the scale. An attachment, for communicating slow motion to the slide is also added. The scale is divided into fortieths of an inch. The vernier contains twenty-five divisions, which cover twenty-four divisions on the scale, and reads thousandths of an inch. The extent of the scale which can be used by the vernier, including the clamp, is 6 inches. In measuring an inside diameter it is necessary to add 0.2 inch to the reading of the instrument for the thickness of the measuring points.

For the measurement of the extension or compression of a specimen while under stress, also the permanent set when relieved from stress, the following instruments are used: (Plate LI.) This instrument consists of a pair of glass slides, which are connected with the specimen by collars in the manner shown. One of the glass slides is graduated to thousandths of an inch, and the other to hundredths of an inch. A microscope using a one-inch objection is employed in reading these scales, and by means of it the scale of thousandths may be readily subdivided into ten thousandths of an inch by the eye alone. The microscope is supported by an adjustable arm attached to one of the posts of the testing machine, or to a post expressly provided for this purpose, and detached from the machine.

2d. *The vernier gauge.* (Plate LI.)—This instrument is similar in principle of construction to the microscopic gauge, except that the glass slides are replaced by a steel scale and a vernier. The former is divided into fortieths of an inch, and by means of the vernier thousandths of an inch can be read. The microscopic gauge is used until the elastic limit of the specimen is reached, after that the vernier gauge is employed. These gauges can be adjusted to any length of specimen beyond 2½ inches by means of additional sections of the rod.

In measuring the deflections of specimens under a bending stress the gauge is attached to the straining stirrup and to the bed of the machine.

Taper-rule. (Plate LI.)—This instrument consists of a graduated steel wedge; the inclination of the wedge being 0''.01 in one inch. The graduation of the scale is in hundredths of an inch, so that each division actually represents an increment or decrement of 0.001 of an inch. A coarser graduation is sometimes employed, and the further subdividing performed by means of a vernier. In using this rule the space between the shoulders of the specimen is inclosed by a tube, excepting a space eight-tenths of an inch in width which is left between the top of the tube and the upper shoulder for the insertion of the rule. The tube is put on in halves, and held in position by bands. Where a vernier is used it is attached to the top of the tube, otherwise an index mark is made on the tube to serve as a zero for the scale. This method of measurement is more laborious and less reliable than with the self-indicating microscopic and vernier gauges described above.

On Plate L is shown the new form of specimen holder now employed with the testing-machine; and Plate LI, the nut which is screwed into the specimen to form the head. This form of head causes a saving in the expense of preparing the specimen for test, and is quite as satisfactory otherwise as the solid turned head.

THE DENSIMETER OR BALANCE FOR THE DETERMINATION OF THE SPECIFIC GRAVITIES OF METALS.

This instrument is simply a form of the hydrostatic balance, and may be employed as a substitute for the hydrometer when a more expeditious process is desired.

DESCRIPION OF THE INSTRUMENT.

(Plate LII.) The instrument consists of a delicate beam-scale, A, having suspended from one extremity of the beam a brass basket, B, perforated with holes. Underneath the basket and supported in a stirrup, D, suspended from the top of the case, is a glass jar, C, to contain water for the immersion of the basket and specimen. A mark is scratched upon the jar near the top, and this mark indicates the height at which the water should, after the immersion of the basket, always stand previous to an experiment. The immersion of the specimen causes

the water to rise above this mark, immersing an additional portion of the suspension-rod of the basket, and the latter loses, in consequence, a slight portion ot its weight in reference to the beam. A correction, therefore, becomes necessary to compensate for this apparent loss in weight. To determine this correction, the suspension-rod is graduated in the following manner: The beam having been thrown into action, and the immersed basket balanced by weights in the pan attached to the opposite arm, a mark is made upon the rod where it is intersected by the surface of the water. The height of the water in the jar is then raised till as much more of the rod is immersed as is likely to occur in practice. Another mark is then made where the rod is now intersected by the water, and the loss of weight in the basket ascertained.

The loss in weight, for the maximum immersion of the rod, amounts to only one-tenth of a grain, while the corresponding length of rod is nearly one inch; the space between the marks, therefore, may be readily subdivided into tenths, and the necessary corrections can thus be read off the rod in actual weight to the nearest tenth of a grain.

Practically, the graduation of the rod is more readily and accurately determined, by a calculation based upon the known weight and length of the rod, and the specific gravity of the material of which it is made.

By using simply a thread in place of the basket, the above correction might be neglected; but the greater convenience offered by the latter has led to its final adoption. The basket is perforated with holes to facilitate immersion, and is, as well as the suspension-rod, gilt electro-plated to preserve it from tarnishing. A thermometer is suspended from the upper edge of the jar, as shown in the plate.

The balance is capable of bearing a charge up to 42,000 grains, and when so loaded, is sensitive to one-fourth of a grain.

Process of taking the specific gravity with the balance.

The process, with this instrument, of taking the specific gravity of a specimen of metal naturally suggests itself. The jar being filled with water to the fixed mark, and the basket suspended therein, the beam is thrown into action, and the weight of the immersed basket ascertained by means of weights placed in the opposite scale-pan. This weight being noted for different temperatures, can be tabulated and thus become a known element for all calculations of the specific gravity. The specimen of metal is then placed in the pan underneath the jar, and weights added to the other pan till the balance of the beam is restored. The sum of these weights is the weight of the specimen in air, plus the weight of the basket in water. The specimen is now transferred from the pan to the basket, and replaced by weights in the pan underneath the jar, till the balance is again restored. The sum of these latter weights is the weight of the volume of water displaced by the specimen, plus the weight lost in the basket, due to the immersion of an additional portion of the suspension-rod. The loss in weight is read off the rod, in tenths of a grain, and is to be substracted from the weights in the pan underneath.

Denote the weight of the basket in water, as first determined, by a; the same weight of basket, plus the weight of the specimen in air, by b; the weight requisite to restore the equipoise after immersion of the specimen by c; the loss of weight in the basket by d; and the correction for temperature by t. Then designating by D the specific gravity of the metal tested:

$$D = \frac{(b-a)\,t}{c-d}$$

that is, the specific gravity is equal to the weight of the specimen divided by the weight of an equal volume of water, at the standard temperature.

Form of record of computation.

Specimen.	Weights.					Logarithms corresponding to—				Density.
	Basket balance in water. a	Specimen balance in air. $+b^{a}$	Specimen balance in water. c	Loss in weight of basket. d	Temperature of water.	$(b-a)$ e	$(c-d)$ f	Weight of water at observed temperature. h	$(e+h-f)$	
Steel.......	820. 5	7139.	805. 3	0. 30	53.	3. 8006140	2. 9057959	.0001775	.8949956	7. 8523

The results obtained with this instrument differ from those obtained with the hydrometer only by about one point in the third place of decimals. It is important in immersing the basket or the specimen that no air bubbles be allowed to form around them, as the results would thereby be materially affected.

HYDROMETER.

Plate LIII exhibits the form of the instrument used in determining the specific gravity of metals. It is constructed on the principle of Nicholson's hydrometer; the bulb is 7.5 inches diameter and 8 inches high, made of copper, in one piece, without seam. The copper is .03 thick, and is deposited on a mold, of low fusible metal, by the electro-galvanic process. A handle of brass wire, with broad flanges at the ends, is inserted in the upper part of the mold, and a cone of brass is inserted in the bottom of the mold, before the copper is deposited, the copper covering and uniting with both. The brass cone is bored through its axis, and screw threads are cut in it. After the bulb is formed, the fusible mold is melted, and withdrawn through the aperture in the brass cone. The aperture is then closed by a small screw, and made air tight by close fitting, and by sealing-wax spread over it. A solid stem of brass is then screwed into the bottom of the bulb. A vertical index stem, made of steel, is inserted in the upper part of the handle. The upper end of the stem receives the weight pan, which is supported in its place by a conical socket on its under side. The height of the hydrometer, from the bottom of the ball to the weight pan, is 21 inches. All of the exterior surface is protected by electro-gilding.

The weight of the bulb, including the handle and brass cone, is about 15,850 grains; the lower stem and ball weigh about 20,320 grains, and the weight-pan 660 grains; making the total weight of the hydrometer about 36,830 grains. Its general form, and the distribution of the metal within it, place the centers of gravity and buoyancy so far apart that it readily takes a vertical position when immersed, and will deviate very little from it, however irregularly it may be loaded.

The maximum buoyancy of the hydrometer is 14,600 grains, and, when loaded to zero, it displaces 51,430 grains of water. The buoyancy may be reduced one-half by increments of 500 grains each, by placing one or more of the adjusting weights over the ball, at the bottom of the stem.

Such a reduction of the buoyancy is found convenient in practice, when weighing small samples, as it prevents the necessity for placing and displacing numerous weights on the pan.

The index stem is .071 inch diameter; a length of 1 inch displaces one grain of water. Four points of silver wire, made thin and sloping at the ends, are attached near the stem, and are so arranged as to form a scale of weights, in tenths of a grain. The two nearest opposite points are one-tenth of an inch apart. When the instrument rests with one of these points above, and the other beneath the surface of the water, it is at its zero. When either of them touches or is even with the surface, the load is one-tenth of a grain too heavy, or too light, and if either passes through the surface, the error is then two-tenths of a grain. If either of the two points which are more distant from the zero touches the surface of the water, the load is then deficient, or in excess, three-tenths of a grain; and if the heel of either of these points passes the surface, the error is then four-tenths of a grain. Careful observation of the position of these points, when the hydrometer is immersed and at rest, will serve to indicate the true balance, when the zero mark may be above or below the surface of the water, within a given limit. By this method, the inconvenience and delay of bringing the zero to the surface of the water by the decimal parts of the grain weight is avoided. Plate LIV gives the form and the dimensions of all the weights used on the pan. The water in which the hydrometer is immersed is contained in a cistern of glass, 25 inches deep, and not less than 12 inches diameter. If the bottom of the cistern is not level a flat plate should be placed over it and be supported horizontally on three legs. The height of the water in the cistern should be such that when the bottom of the hydrometer descends to the plate the weight-pan shall be one-quarter inch above the surface of the water. This will prevent an immersion of the pan when overloaded.

The weight-pan is attached to the index stem by an open socket, on its under side, in order that it may be removed with its load from the hydrometer and placed on a table where the weights may be more safely and accurately counted. As the weights do often consist of many pieces, errors may occur in counting, or in the record of them; it is a good precaution to verify them by a recount after making the record.

A thermometer, with a scale of about 5° to the inch, subdivided in quarters of a degree, is suspended in the water while weighing samples and the temperature is noted at each weighing. The weighings are made at temperatures varying with the state of the weather at the time, and as the density of water varies with its temperature, the latter is noted in order that the proper corrections may be made. The unit adopted is distilled water at the temperature of 60° Fahr.

The hydrometer may be employed to determine the relative density of distilled and any other kind of water. The weight of the hydrometer, added to its balance weight in distilled water, at the temperature of 60°, gives the weight of a quantity of pure standard water which is equal in bulk to the immersed part of the instrument. The weight of the hydrometer, and its load, when immersed in like manner in any other kind of water at the same temperature, gives the weight of an equal bulk of the latter; and this weight, divided by the former, gives the multiplier for correcting the density when ascertained in any other than pure distilled water.

Rain or river water may be used instead of distilled water, if its relative density be first accurately determined and the proper correction be made. At the foundries, generally, river water is found to be sufficiently pure for use without needing any correction.

In using the hydrometer, first load the pan with grain weights until the instrument rests at zero, and record the sum of these weights as the

balance of the hydrometer. Next, place in the pan the sample, together with as many weights as will again bring the instrument to its zero, and record these weights as the *sample balance in air.* The difference between these balances is equal to the weight of the sample in air. Then place the sample on the bulb of the instrument and immerse both until the hydrometer again rests at zero, and record the weights on the pan as the *sample balance in water.* The difference between this balance and that in air is equal to the weight of the water displaced by the immersed sample. The temperature of the water at the time of weighing is noted, and if it is not at 60° divide the weight displaced by the sample by that number in the following table which is opposite the noted temperature, and the quotient will give the corrected displacement for the temperature of 60°. Then, the weight of the sample in air, divided by the corrected displacement, gives the density of the sample.

The hydrometer may be employed in determining the varying density of the same water at different degrees of temperature. The weight of water it displaces at any other temperature than 60°, divided by its displacement in the same water at 60°, will give the proportionate weight of water displaced by the same instrument at other temperatures.

The following table has been compiled from Mr. Hassler's Report on Weights and Measures, made to Congress in 1832. He ascertained the weight of water displaced by a given glass bulb at 215 different temperatures, varying from 32° to 86° Fahr. The weighings were made from time to time, at whatever temperature the changes of the weather gave at the moment. As the results obtained in this form were not conveniently applicable for common use, they have been reduced to equal divisions of the thermometrical scale for each quarter of a degree. The reductions were made by marking on a large map the points determined by Mr. Hassler, and by tracing a line through all the points, and then by measuring this curved line at divisions corresponding to quarter degrees.

The weights given in the table do not represent the absolute density of water at different temperatures, but only the proportionate weights displaced by the same glass bulb. The varying bulk of the latter in different temperatures is not taken into account, as it compensates very nearly for the varying bulk of the metals weighed in corresponding temperatures. A column containing the logarithms of the weights is added to the tables for convenience in making the computations.

Form of record of computation.

Specimens, material, &c.	Hydrometer balance. a	Specimen balance in air. b	Specimen balance in water. c	Temperature of water.	Logarithms corresponding to— $a-b$ d	$c-b$ e	Temperature of water. f	$d+f-e$	Density.
Wrought iron	11004	7378	7850	° 62.5	3.5594278	2.6739420	1.999928	0.8854138	7.6810

Weight of distilled water displaced by the same glass bulb at different temperatures.

Temperature.	Weight of water.	Logarithms of weight.	Temperature.	Weight of water.	Logarithms of weight.	Temperature.	Weight of water.	Logarithms of weight.
32.00	1.000395	0.0001706	50.25	1.000517	0.0002244	68.50	0.999297	-1.9996945
32.25	1.000406	0.0001764	50.50	1.000508	0.0002207	68.75	0.999273	-1.9996843
32.50	1.000420	0.0001825	50.75	1.000499	0.0002168	69.00	0.999249	-1.9996740
32.75	1.000433	0.0001880	51.00	1.000490	0.0002130	69.25	0.999226	-1.9996636
33.00	1.000444	0.0001928	51.25	1.000482	0.0002091	69.50	0.999202	-1.9996532
33.25	1.000455	0.0001975	51.50	1.000472	0.0002050	69.75	0.999178	-1.9996477
33.50	1.000467	0.0002028	51.75	1.000462	0.0002007	70.00	0.999153	-1.9996320
33.75	1.000479	0.0002078	52.00	1.000452	0.0001961	70.25	0.999127	-1.9996208
34.00	1.000489	0.0002123	52.25	1.000441	0.0001915	70.50	0.999102	-1.9996098
34.25	1.000499	0.0002167	52.50	1.000430	0.0001869	70.75	0.999076	-1.9995985
34.50	1.000510	0.0002214	52.75	1.000419	0.0001821	71.00	0.999050	-1.9995873
34.75	1.000519	0.0002253	53.00	1.000409	0.0001775	71.25	0.999024	-1.9995779
35.00	1.000527	0.0002288	53.25	1.000398	0.0001727	71.50	0.998997	-1.9995642
35.25	1.000536	0.0002329	53.50	1.000387	0.0001679	71.75	0.998969	-1.9995522
35.50	1.000545	0.0002366	53.75	1.000374	0.0001625	72.00	0.998942	-1.9995401
35.75	1.000553	0.0002401	54.00	1.000363	0.0001574	72.25	0.998912	-1.9995274
36.00	1.000560	0.0002432	54.25	1.000349	0.0001515	72.50	0.998884	-1.9995150
36.25	1.000566	0.0002459	54.50	1.000337	0.0001465	72.75	0.998855	-1.9995027
36.50	1.000572	0.0002483	54.75	1.000322	0.0001398	73.00	0.998825	-1.9994892
36.75	1.000577	0.0002504	55.00	1.000307	0.0001348	73.25	0.998795	-1.9994765
37.00	1.000581	0.0002528	55.25	1.000296	0.0001286	73.50	0.998766	-1.9994635
37.25	1.000586	0.0002542	55.50	1.000282	0.0001223	73.75	0.998736	-1.9994506
37.50	1.000589	0.0002561	55.75	1.000267	0.0001161	74.00	0.998705	-1.9994373
37.75	1.000595	0.0002581	56.00	1.000254	0.0001103	74.25	0.998675	-1.9994241
38.00	1.000599	0.0002603	56.25	1.000239	0.0001040	74.50	0.998645	-1.9994113
38.25	1.000604	0.0002622	56.50	1.000224	0.0000973	74.75	0.998615	-1.9993979
38.50	1.000609	0.0002642	56.75	1.000209	0.0000910	75.00	0.998584	-1.9993845
38.75	1.000614	0.0002666	57.00	1.000195	0.0000846	75.25	0.998553	-1.9993710
39.00	1.000619	0.0002685	57.25	1.000181	0.0000783	75.50	0.998521	-1.9993574
39.25	1.000628	0.0002725	57.50	1.000165	0.0000717	75.75	0.998492	-1.9993446
39.50	1.000635	0.0002755	57.75	1.000148	0.0000644	76.00	0.998461	-1.9993313
39.75	1.000642	0.0002786	58.00	1.000133	0.0000579	76.25	0.998430	-1.9993175
40.00	1.000646	0.0002806	58.25	1.000118	0.0000512	76.50	0.998399	-1.9993039
40.25	1.000649	0.0002817	58.50	1.000101	0.0000439	76.75	0.998367	-1.9992904
40.50	1.000650	0.0002821	58.75	1.000085	0.0000368	77.00	0.998337	-1.9992771
40.75	1.000650	0.0002821	59.00	1.000068	0.0000296	77.25	0.998309	-1.9992649
41.00	1.000649	0.0002819	59.25	1.000051	0.0000222	77.50	0.998278	-1.9992515
41.25	1.000649	0.0002815	59.50	1.000034	0.0000149	77.75	0.998248	-1.9992382
41.50	1.000647	0.0002810	59.75	1.000017	0.0000072	78.00	0.998216	-1.9992244
41.75	1.000645	0.0002802	60.00	1.000000	0.0000000	78.25	0.998184	-1.9992104
42.00	1.000644	0.0002796	60.25	0.999981	-1.9999919	78.50	0.998152	-1.9991965
42.25	1.000643	0.0002792	60.50	0.999963	-1.9999839	78.75	0.998120	-1.9991826
42.50	1.000642	0.0002787	60.75	0.999945	-1.9999760	79.00	0.998080	-1.9991686
42.75	1.000641	0.0002781	61.00	0.999927	-1.9999681	79.25	0.998055	-1.9991545
43.00	1.000639	0.00002774	61.25	0.999909	-1.9999603	79.50	0.998022	-1.9991400
43.25	1.000637	0.00002766	61.50	0.999890	-1.9999522	79.75	0.997989	-1.9991258
43.50	1.000635	0.00002756	61.75	0.999871	-1.9999440	80.00	0.997956	-1.9991113
43.75	1.000633	0.00002748	62.00	0.999853	-1.9999361	80.25	0.997923	-1.9990970
44.00	1.000631	0.0002740	62.25	0.999834	-1.9999280	80.50	0.997889	-1.9990822
44.25	1.000629	0.0002731	62.50	0.999814	-1.9999193	80.75	0.997855	-1.9990673
44.50	1.000626	0.0002721	62.75	0.999795	-1.9999108	81.00	0.997821	-1.9990526
44.75	1.000624	0.0002710	63.00	0.999774	-1.9999020	81.25	0.997788	-1.9990383
45.00	1.000621	0.0002699	63.25	0.999753	-1.9998929	81.50	0.997754	-1.9990233
45.25	1.000619	0.0002687	63.50	0.999733	-1.9998840	81.75	0.997718	-1.9990079
45.50	1.000619	0.0002675	63.75	0.999712	-1.9998749	82.00	0.997681	-1.9989918
45.75	1.000613	0.0002660	64.00	0.999692	-1.9998660	82.25	0.997644	-1.9989756
46.00	1.000610	0.0002646	64.25	0.999672	-1.9998574	82.50	0.997604	-1.9989596
46.25	1.000606	0.0002631	64.50	0.999651	-1.9998483	82.75	0.997571	-1.9989438
46.50	1.000602	0.0002615	64.75	0.999629	-1.9998388	83.00	0.997536	-1.9989286
46.75	1.000598	0.0002598	65.00	0.999608	-1.9998294	83.25	0.997500	-1.9989138
47.00	1.000594	0.0002578	65.25	0.999585	-1.9998198	83.50	0.997468	-1.9988989
47.25	1.000589	0.0002558	65.50	0.999563	-1.9998104	83.75	0.997433	-1.9988837
47.50	1.000584	0.0002537	65.75	0.999542	-1.9998011	84.00	0.997398	-1.9988684
47.75	1.000579	0.0002515	66.00	0.999521	-1.9997918	84.25	0.997363	-1.9988532
48.00	1.000574	0.0002493	66.25	0.999499	-1.9997822	84.50	0.997327	-1.9988378
48.25	1.000569	0.0002470	66.50	0.999479	-1.9997737	84.75	0.997292	-1.9988223
48.50	1.000564	0.0002448	66.75	0.999454	-1.9997630	85.00	0.997256	-1.9988068
48.75	1.000558	0.0002421	67.00	0.999432	-1.9997553	85.25	0.997220	-1.9987908
49.00	1.000551	0.0002393	67.25	0.999409	-1.9997435	85.50	0.997183	-1.9987750
49.25	1.000545	0.0002366	67.50	0.999387	-1.9997338	85.75	0.997150	-1.9987604
49.50	1.000538	0.0002336	67.75	0.999365	-1.9997243	86.00	0.997116	-1.9987456
49.75	1.000531	0.0002306	68.00	0.999343	-1.9997146			
50.00	1.000524	0.0002276	68.25	0.999320	-1.9997047			

THE BOULENGÉ CHRONOGRAPH.

[From Capt. O. E. Michaelis' translation.]

INTRODUCTION.

In this instrument the time between two events is ascertained by noting the distance of the *free* fall of a heavy body during the interval, the beginning and end of this distance being made to accord with the occurrence of the events by means of the galvanic current.

THE INSTRUMENT.

The chronograph of Captain Le Boulengé can be used not only as a micro-chronometer, but directly as a velocimeter. Plate LV shows the instrument ready for use; for taking velocities, and for measuring minute intervals of time. To obtain velocities at once,* two electric circuits are established a fixed distance, say fifty meters, apart, in such a manner as to be successively broken by the projectile in its flight. The first current circulates through the electro-magnet A, whose armature is a long cylindrical rod, C, called the *chronometer*, furnished with two enveloping zinc tubes, D and E, called *recorders*. The second current passes by the electro-magnet B, whose armature, the shorter rod F, is called the *registrar*. The third active element of the instrument is the *indenter* (Plate LVI), consisting of the circular knife G, fixed in the mainspring H, which can be cocked by means of the catch on the lever I.

On the breaking of the first circuit, the chronometer falls vertically; on the rupture of the second the registrar falls in its turn, depresses the free end of the lever I, and thus releases the mainspring; the knife juts forward, strikes the falling chronometer, and indents the upper recorder. As shown below, a very simple relation holds between the dent thus obtained and the velocity of the projectile which caused it. Even with this brief description, a moment's thought will show that the lower the velocity the higher up shall the recorder be indented.

THEORY OF THE INSTRUMENT.

The above succinct account of the action of the instrument is sufficient for a comprehension of its theory. The details of construction will be given when we come to speak of its use.

As an *origin* of reference for the falls of the chronometer, we take the dent imprinted on the lower recorder, when the knife is "let off," while the chronometer is suspended.

Let h be the height above the origin of the dent due to the shot; then, as the chronometer followed the law of falling bodies from the beginning of its movement up to the time it was struck by the knife, we have $T' = \sqrt{\frac{2h}{g}}$ as the time corresponding to this fall. It would also be the time of the trajectory between the targets (giving a velocity of $\frac{50}{T'}$ meters to the projectile), provided the chronometer began its fall at the precise instant the first, and the knife struck it at the precise instant the second, current was broken. But this is, in reality, not so; for, after the breaking of the first current, a certain interval, θ, elapses before the electro-magnate is sufficiently demagnetized to permit the fall of the chronome-

* At Watertown Arsenal and Sandy Hook the targets are one hundred feet apart.

ter, which will accordingly be retarded by this time, and the observed duration of the trajectory will be too small by the same quantity.

On the other hand, from the breaking of the second current up to the instant of the knife striking the chronometer, the following intervals elapse:

θ' for the sufficient demagnetization of the electro-magnet B.

t' for the fall of the registrar to the disk of the indenter.

t'' for the release of the catch.

t''' for the knife to clear the horizontal distance to the falling chronometer.

The observed time, T′, is then too great by the quantity $(\theta' + t' + t'' + t''')$, and too small by θ. For the true time of flight, T, we have, therefore, $T' - (\theta' + t' + t'' + t''' - \theta) = T' - t$. For $T \doteq o$, we have $T' = t$, whence to obtain the value of t we have only to break both circuits simultaneously, and note the resulting time of fall; since, after this common rupture, there passes the time θ before the chronometer falls, and $(\theta' + t' + t'' + t''')$ before it is struck, until it is dented there elapses then the time $(\theta + t' + t'' + t''' - \theta)$ or t. As will be shown presently, the instrument can be so adjusted as to give t a constant value, say $0''.15$.

Whenever desirable, we can ascertain if the apparatus is thus adjusted or not, by using the *disjunctor* (Plate LVI), which is in both circuits. If the resulting dent is 110.29^{mm} above the origin (the height corresponding to $0''.15$ at Watertown Arsenal), the instrument is properly set. Dependent upon this condition, we can fix in advance the height corresponding to any given velocity of projectile. For example, with an initial velocity of 500 meters, the projectile will pass over the 50 meters' interval between the circuits in $0''.1$, and the instrument will record $0''.15 + 0''.1$, or $0''.25$, and the height will therefore be

$$H = \frac{9.8037 \times 0''.25^2}{2} = 306.36^{mm}.$$

Reciprocally, if the shot gives a dent 306.36^{mm} above the origin, we conclude that the projectile was moving with a velocity of 500 meters.

The heights corresponding to all velocities within the ordinary limits of experiments have been calculated and inscribed on a metal rule, furnished with a sliding index (Plate LVII), which thus affords a simple means for *directly* measuring the velocity of the projectile fired. The shot having given the indent, we adjust the rule to the chronometer, slide the beak of the index into the notch, and read off the velocity.

USE OF THE INSTRUMENT.

As has already been stated, when it is desired to measure velocities directly, two targets must be set up 50 meters apart. The chronometer circuit passes through the first, and the registrar through the second, the disjunctor being in both. Should local difficulties intervene to prevent the targets being set up exactly 50 meters apart, multiply the velocity read from the scale by the constant ratio $\frac{D}{50}$ where D is the actual space in meters.

For transport, the different parts of the instrument are packed in a box, which also serves as a stand for mounting it. After unpacking the box screw on the sectional iron tripod, then stand it independently of the floor, so that it may be subject to as little vibration as possible, and fasten in its place the triangular plate that carries the indenter and col-

umn. The electro-magnets are attached by passing the threaded stems through the column, and tightening with the milled nuts (Plate LV).

The disjunctor should be placed near the instrument, within easy reach of the operator. Ordinarily, one seven-inch chromic potash cup will be found sufficient for the registrar circuit, and three cups for the chronometer.

As so little power is required, we would recommend, if easily attainable, that Daniell's or Hill's batteries be used as giving most constant action.

Two recorders are put on the chronometer. To put on the smaller, unscrew the bob (Plate LVII). These tubes should be lightly tapped, before being slipped on, to insure a snug fit. Care must be taken that the lower recorder rests closely against the bob.

The currents being properly established and sufficiently strong to enable the magnets to maintain the rod-armatures, the next step is the adjustment of the apparatus, which comprises these three operations:

1. Leveling the instrument.
2. Regulating the power of the electro-magnets.
3. Fixing the height of the disjunctor-reading.

Leveling the instrument.—The chronometer is used in leveling; for this purpose attach it to its magnet, *having previously cocked the indenter;* then, by means of the tripod-screws, bring it to its normal position. In leveling from front to rear, let the beveled shoulder of the bob, opposite the numbered face, rest lightly against the projecting edge *c c* (Plate LVI) of the triangular base; in leveling laterally, align the right face with the edge *d d* of the salient angle of the above projection.

Regulating the electro-magnets.—It is very advantageous to work with weak magnets, as we need not then take into account the troubles due to "remaining magnetism"; still the magnets must be strong enough, else the operator will have difficulty in suspending the armatures.

Captain Le Boulengé has adopted the following simple and ingenious plan for making the electro-magnets just sufficiently powerful for their work. He increases the weight of the armatures one-tenth by means of brass tubes (Plate LVI) which are supplied with the instrument. Thus weighted, attach the chronometer, with the recorders on, to its magnet, and gently and gradually withdraw the core, until the armature falls. To make certain that this has been correctly done, attempt to suspend the chronometer; if it hang, its fall was due to some accidental shock, and the core must be still further withdrawn.

Having thus regulated the magnet, remove the weight, and no trouble will be experienced in suspending the rod. The other magnet is regulated in exactly the same way by the registrar and its weight. In this manner the instrument is always regulated by a fixed standard, whoever may be the operator—a very great advantage in practice, as all errors arising from "personal equations" are thus eliminated.

The method of operating the disjunctor, which is extremely simple, may be explained at this point. To close it, press with the finger on the milled stud *z* (Plate LVI) until the mainspring *t* is held by the catch *x*, which establishes the circuits by bringing the blades *q q′* in contact with the pins *r r′*. To open it, press the catch *x* with the finger, the thumb at the same time grasping the post *y*, until the mainspring is freed, whose cross-piece, *u*, covered with some insulating material, lifts the blades simultaneously from contact with their respective pins.

In cocking the indenter, be careful not to disturb the level of the instrument; the left hand alone is therefore used; the fingers grasp the tube L, while the thumb pulls back the spring until it catches in the lever I.

The screw M, which is tapped through the lever and rests on the fulcrum-mortise, regulates the hold of the catch, which should be as light as possible. The knife is a circular rowel of tempered cast-steel, fastened in a slot of the mainspring by the axial screw N, the loosening of which permits the presentation of a new edge, should the old one be blunted.

Fixing the disjunctor reading.—The disjunctor dent, to be properly placed on the chronometer, should be, as has already been mentioned, 110.29^{mm} above the origin (at Watertown Arsenal) which represents the time $0''.15$. This height should be indicated on the rule by a special mark. (On the one sent by Captain Le Boulengé it is marked "disjonction," and is 110.37^{mm} above the origin.) That this disjunctor adjustment may be accomplished quickly, begin by tracing on the smaller recorder a circle at the desired height (110.29^{mm}). For this purpose, slide the vernier along the scale (Plate LVII) until its index coincides with the "disjunction" mark, and clamp it. Now, place the chronometer flat on a table, the numbered face toward the body, insert the hinged conical pin of the rule in the tapering hole of the bob, and let the vernier-knife rest on the zinc tube. Support the end of the rule with the right hand, and press it on the bob, while the left turns the recorder. In this manner a fine circle is traced, on which, if the instrument is well adjusted, the disjunction marks should be indented. This rule is so constructed that its scales begin at the height of the origin, to which the dents are referred. It has been found convenient to add a slow-motion screw to the slide.

The cut made by the indenter-knife is a wedge-shaped notch, clearly nicked in the zinc, whose edge is in a plane perpendicular to the axis of the cylinder. As the section of this plane is the true indent, the vernier-knife must be brought against it in measuring. This knife fits accurately to the edge of the notch, thus eliminating all errors of reading. This has been tested by allowing several persons to measure the height of the same dent, whose results have agreed exactly. Everything being ready, a disjunctor reading is taken; if the resulting dent is on the circle already traced, no further regulating is required, and the firing may commence at once. But if the dent is above the circle, the fall of the registrar must be diminished; if below, increased. This is done by raising or lowering the disk O, (Plate LVI) which is supported on an upright screw having a pitch of one millimeter, and is divided on its circumference into ten equal parts, so that its height may be varied by a tenth of a millimeter.

A pawl, P, playing in the nicks of the disk renders it easy to count its turns, and to fix it at the desired height. The reading having been once adjusted will not vary more than a few tenths of a millimeter at a subsequent experiment, and this can at once be regulated by turning the screw through the same number of divisions.

The instrument is set up for firing in the same manner as for taking a disjunctor reading. To avoid confusion, numbered ink-marks about one-sixteenth of an inch apart are made around the bases of the two recorders, and each mark is successively brought in line with the cut, A B, on the ring (Plate LVI), as the firing progresses, by which means the dents are made on equidistant straight-line elements. The zincs can thus receive about twenty dents, and then be turned end for end and receive twenty more. The shot having given a dent, apply the rule to the chronometer in the manner described for tracing the disjunction circle, bring the vernier-knife against the edge of the notch, clamp it, and read off the velocity. The experiments for the day being over, the date is inscribed on the proper recorder, and, if deemed necessary, it may be filed for future reference.

If the foregoing directions as to the setting-up and adjustment of the instrument are carefully followed, not only will there be no appreciable variation in the disjunctor-readings before any shot, but they will, as a rule, remain constant from round to round.

THE INSTRUMENT AS A MICRO CHRONOMETER.

When the chronograph is used, as heretofore described, with an interval of 50 meters or more between the targets, the chronometer receives the dents near the top, when of course it is moving with its greatest speed, and, consequently, small differences in time give proportionately large differences in height. But when the interval to be measured becomes small this no longer obtains, for then the dent of the shot is imprinted on the *lower* recorder near the disjunction circle before the chronometer has acquired much acceleration. To obviate this difficulty the arrangement shown in Plate LV is adopted.

The electro-magnet of the registrar with its stop is removed to the upper part of the column, and *introduced in the circuit that is broken first.* By this arrangement we obtain a disjunction dent near the *upper* end of the chronometer, and thus regain the advantage, even when the interval is very small, of recording minute times where the representative scale is greatest. This disjunctor-reading is about 0″.3, double what it was before, hence the representative dents of small times are marked on the chronometer when it has double its former velocity.

We may remark here that for diminishing velocities and in measuring small times for decreasing intervals, the units of the scale in the one case and the corresponding spaces on the chronometer in the other increase—most desirable attributes of instruments of this class.

All that has already been said concerning the leveling, adjustment, and management of the apparatus applies here, except that the disjunctor-reading is not regulated, and must be taken for each round, and further, as has already been stated, that the registrar is in the circuit of the first target.

The fall corresponding to the time to be measured is recorded *negatively*, as the firing dent is below the disjunctor-reading, and the duration of this fall is found by subtracting that of the former from the latter. These heights are measured to tenths of a millimeter by means of the scale engraved on the rule and its vernier, and the corresponding times may be calculated from the formula $T=\sqrt{\frac{2H}{g}}$, or taken directly from a table, which is formed analogously to the ordinary logarithmic tables. When the interval becomes so great as to give a dent below the upper recorder, the ring on the rod must be removed, and two of the larger tubes applied to the chronometer, one above the other. The largest interval that can be recorded by the instrument thus arranged is that which corresponds to the disjunctor-reading, a little over 0″.3. When the time between the rupture of the two circuits exceeds this reading, the chronometer is struck before it has commenced to fall, and the dent of the origin is obtained.

PRESSURE-GAUGES.

(Plates LIX to LXII.)

The pressure of the gas per square inch in the bore of the gun is determined by means of the pressure-gauge.

The principle of this instrument is as follows: The pressure due to

the tension of the confined gas is transmitted through a piston to a knife, in contact with a piece of soft copper, whereby the knife is forced into the copper, making an indentation, the length of which will depend upon the amount of pressure exerted. The length of this indentation is measured, and the pressure is determined from the pressure actually applied with the testing machine, to produce, with the same knife and the same area pressed as that of the piston, an indentation of an equal length in a similar piece of copper. To facilitate operations, a table is usually prepared beforehand, showing the pressure corresponding to any given length of indentation likely to occur in practice. The instrument consists essentially of five parts (Plate LIX):

1st. The *housing:* A cylindrically-shaped box, *a*, of steel, which contains all the parts of the instrument, and supports them in their proper relative positions for use. It is closed either at top or bottom by a screw-plug.

2d. The *piston b*, which is of steel, and of a diameter to correspond to some definite portion of one square inch, as $\frac{1}{4}:\frac{1}{10}:\frac{1}{20}$, &c.

3d. *The knife or indenting tool* (*c*).—Several forms of knife are used, as shown in the Plate LIX, and are designated as pyramidal, Figs. 1 and 3; round, Fig. 2; and spiral, Fig. 4. The round knife is cut from a circular disk, as shown in Fig. 2 (Plate LIX), a method of manufacture that admits of making a number of knives identical in form and dimensions.

4th. The *copper disk or block d*, for receiving the indentations of the knife. It is of pure annealed copper.

5th. The *gas check e*, a thin copper cup to prevent the gas from entering the interior of the housing. In Fig. 4, a leather washer, fitted into a groove cut round the piston, is substituted for the copper cup.

The several forms of pressure-gauges, cutters, and mode of attachment to cartridge bags, are shown on plates LIX, LX, LXI, and LXII.

Plate LIX, Fig. 1, represents a form of external pressure-gauge for taking pressures at the bottom or at any point along the surface of the bore. The length of the plug in which the gauge is screwed is such that its bottom reaches to and forms a part of the bore at the position where the pressure is to be taken. The plug has a sectional screw to facilitate its insertion or withdrawal, and the rim of the plug is provided with a gas-check to cut off the gas from the surface of the plug.

Figs. 2 and 3 are forms of internal pressure-gauges, showing their construction and means of attachment to the cartridge-bag.

Fig. 4 shows a form of internal pressure-gauge proposed by Dr. W. E. Woodbridge. It consists essentially of a piston having a conical cavity, pressed by the powder-gauge against a disk of copper which enters the cavity in proportion as it is crushed. The surface of the cavity is formed with a fine spiral thread, continuous from the face of the piston to the apex of the cone—the turns of their threads being divided into tenths by lines radiating from the apex. These are impressed upon the copper according to the extent that the metal has been forced into the cavity, and a reading of the number of turns of the spiral affords an indication of the pressure to which the piston has been subjected. It may be considered to be a modification of a form of internal gauge proposed by Capt. H. Metcalfe, Ordnance Department, the spiral cutter of which is convex. The cut on the disk is divided for facility of reading the pressure.

Fig. 5 shows a form of internal pressure-gauge in use in England, called the "Crusher Gauge."

The *crusher-gauge* consists of a screw-plug of steel (Plate LIX, Fig. 6),

with a movable base, which admits the copper cylinder B; one end of the cylinder rests against the anvil A, while the other is pressed by the movable piston C, kept against the cylinder by an annular spring, *i*; the cylinder is centered in the chamber by a small watch-spring, to prevent the escape of gas to the chamber; the head of the piston and body of the anvil is fluted; four small holes, *a b*, communicate with the main vent through the upper part of the plug; a gas-check, D, is placed against the lower end of the piston.

The action of the gauge is as follows: The gas, acting on the piston, crushes the copper cylinder against the anvil; the amount of compression it sustains indicates the pressure. The area of the copper cylinder for 8-inch guns is $\frac{1}{12}$ of a square inch; that of the piston being $\frac{1}{6}$ of a square inch.

A table of results to produce definite amounts of pressure by the testing-machine affords a means of comparison of the results produced in the gun at different points of the bore.

Use.—The pressure-gauge having been carefully oiled and put together, is usually placed either at the bottom of the cartridge-bag, where it is secured by a piece of twine, passing round the groove *f* (care must be taken that the bottom of the internal pressure-gauge is against the bottom of the bore, or the resulting pressure will be unreliable), or it is inserted through an aperture in the wall of the gun, and supported by screw-thread, as indicated by its construction.

The device shown on Plate LXII has also been employed. It consists simply of a bronze or steel cup of the same form as the bottom of the bore, and attached to the pressure-gauge by a stout screw. The pressure of the gas upon the cup holds the gauge firmly in position during discharge.

After firing, the gauge is removed from the gun, opened, the copper disk taken out, and the length of indentation measured. In reading the disk where the spiral cutter is employed, commence at the heavy radial cut and count the ridges of the thread, then to the right of the radial divisions to the end of the indentation. The ridges will give the number of turns, and the divisions the tenths.

Accessories.—Plate LXI. These consist of the wrenches used for opening and closing the gauges; and the taper rule for measuring the length of the indentation.

MODE OF TAKING GUTTA-PERCHA IMPRESSIONS OF THE BORES OF GUNS.

(Plates LXIII, LXIV.)

Gutta-percha impressions of a portion of the bore of a gun are conveniently taken by means of wooden blocks or wedges. For this purpose two blocks are used, one about two-thirds the length of the other; the longer block carries the gutta-percha for the impression, the shorter one is used as a wedge. Each block has a staff longer than the bore of the gun, enabling the operator at the muzzle to place the blocks in any desired position in the bore, drive the wedge, and withdraw the blocks. These blocks are so shaped (see plates) as to form an imperfect cylinder whose diameter is less than that of the bore, enabling the longer block to carry the gutta-percha to the required place in the bore. By driving the wedge, the diameter of this cylinder is increased nearly to that of the bore; the gutta-percha is pressed against the surface of the bore, and forced by the driving wedge to take the impression.

Before taking an impression the gun should be thoroughly washed out and oiled with an oiled sponge; the gutta-percha, softened by hot

water, just below the boiling point, to the required consistency—about that of putty—is then placed on the block, well oiled, worked and kneaded with oil until it is spread over the required portion of the block. The blocks are also well oiled, particularly the surfaces which come in contact. The two blocks are put together at the muzzle, and both together are pushed into the bore to the distance desired, marked on the staff of the carrying-block. The carrying-block is held steady by its staff, while the wedge-block is driven in by several blows of a sledge on the end of its staff; from two to five minutes is sufficient to allow it to set. The wedge-block is withdrawn first and the carrying-block with the impression afterwards. To withdraw the wedge-block, an iron pin is run through the staff near the end, and struck with the sledge until it starts, when it is easily withdrawn. The carrying-block will generally fall or release itself by its own weight, bringing the impression with it, if the impression is taken anywhere in the upper half of the bore. Where an impression is wanted from the bottom of the bore, a small block or rider is pushed in at the same time as the carrying-block (see plate), so as to keep the gutta-percha from touching the surface of the bore while being pushed into place. Afterwards the rider-block is withdrawn, the wedge driven in, and after the wedge is withdrawn the rider-block is pushed back close to the carrying-block, and acts as a fulcrum by which the impression is raised free from the bore, when both are withdrawn together.

In taking an impression on the side, it is better to push in the blocks as in taking the impression above, and then to turn the blocks to the side. Unless the block under the gutta-percha is well oiled, some difficulty may be experienced in releasing the impression from the block.

The carrying-block should have a slight raised edge on each side or the upper surface of the block, to prevent the gutta-percha from spreading out too much when undergoing the pressure from the wedge, and also to protect it when turning the blocks for side impression. Impressions are marked by their distance from the muzzle in inches; the name, number, and caliber of the gun, and whether taken at top, bottom, right, left, top right, top left, bottom right, bottom left, of the bore, when facing the muzzle.

A convenient size to obtain the gutta-percha is in slabs twenty inches long, five inches wide, and five-eighths of an inch thick. Each slab will make, ordinarily, two or three impressions, and can be used several times if desired.

FORMULAS PERTAINING TO RIFLED GUNS.

I.

To give to the projectile rotation about its longer axis, rifled guns have grooves cut spirally in the bore, the angle of spiral varying in different guns, depending mainly upon the weight, length, and initial velocity of the projectile. It is measured at any point of the groove by the angle which a tangent to the groove at that point makes with an element of the bore; it is evident that this angle is constant in guns rifled with *uniform twist*.

In guns rifled with *increasing twist*, the angle at the breech is called the *initial angle of rifling;* at the muzzle, the *final angle of rifling.*

The *twist of rifling* (ordinarily expressed in calibres) with uniform twist is designated by the distance in which the spiral makes one com-

plete turn; with an increasing twist it is designated at any point by the distance in which the spiral would make a complete turn with the inclination due to the angle at that point.

Let

l = angle of spiral at any point of bore.

u = twist of rifling (in calibers) at same point.

Then

$$\tan l = \frac{\pi}{u},$$

expressing the relation between the angle of spiral and twist of rifling at a given point of bore.

II.

Initial velocity of rotation.

Let V be the initial velocity of the projectile or space it would pass over in one second in the direction of flight, moving with the velocity with which it leaves the piece, and l the distance passed over by the projectile in making one revolution; therefore $\frac{V}{l}$ will be the number of revolutions in one second, and $2\pi\frac{V}{l}$ the *angular velocity* of the projectile at the muzzle. The velocity of rotation of a point on the surface is given by the expression

$$rw = 2\pi r\frac{V}{l}$$

in which r is its distance from the axis of motion, and w is the angular velocity.

III.

Inclination of grooves.

The object of rifle grooves being to communicate an effective rotary motion to a projectile throughout its flight, it remains to determine what velocity of rotation, or inclination of grooves, is necessary for different projectiles.

The velocity of rotation will depend on the form and initial velocity of the projectile, the causes which retard it, and the time of flight; therefore, *there is a particular inclination of grooves which is best suited to each caliber, form of projectile, charge of powder, and angle of fire.*

Substituting for l in the above formula its value, $l=nd$, we have $rw=2\pi r\frac{V}{nd}$, in which $n=$ number of calibers in one turn of the rifling; d=caliber in feet.

With regard to the velocity of rotation, we must impart to the shot a sufficient amount of kinetic energy of rotation (or work stored up due to rotation) to keep it steady up to the farthest range required.

As the shot leaves the muzzle, its kinetic energy of rotation is expressed by the formula $\frac{w^2}{2}Mk^2$

where w = angular velocity at muzzle $= 2\pi\frac{V}{nd}$; M = mass of the projec-

tile $= \frac{W}{g}$; W = weight of projectile in pounds; $k^2 =$ (radius of gyration)$^2 = \frac{d^2}{8}$ *; $\pi = 3.14159$.†

We do not know, however, the rate at which rotation is retarded (not knowing what is the coefficient of friction of the air), and therefore can only determine, experimentally, the amount of energy of rotation to be imparted, in order that the spot shall be stable at its maximum range.

The twist necessary (with a given velocity) in a particular gun to determine the shot leaving the muzzle with sufficient energy of rotation being known, we can find out, approximately, the twist required for another piece firing the same projectile, but having a different initial velocity, for the kinetic energy of rotation varies with the angular velocity, and that again with the initial velocity and length of twist.

Take, for example, the case of an 8-inch gun, where initial velocity 1,400 f. s., and suppose that we want to know what twist we should give to an 8-inch howitzer, which is to throw the same projectile, but the initial velocity of which we require to be low, as it is intended for high angle fire.

We want, say, an initial velocity of 550 f. s., supposing the time of flight to be about equal; then the D or angular velocity must be the same in each case, and we have

$$D = 2\pi \frac{V}{nd} = 2\pi \frac{1400}{40'd}$$

for 8-inch gun;

$$D = 2\pi \frac{v}{n'd} = 2\pi \frac{550}{n'd}$$

for 8-inch howitzer; but these are equal; therefore,

$$\frac{2}{n'} = \frac{55}{7} \text{ or } n' = \frac{110}{7} = 15.7$$

or the twist should be about 1 in 16 calibers.

THE EFFECTS PRODUCED BY HEAVY GUNS.

The effects produced by the projectile of a heavy gun by its power of piercing iron plates: This power is found (with projectiles of the same form, material, and weight) to vary, approximately, with the kinetic energy of the projectile, and inversely as its diameter or circumference in some functions of the same. The experiments carried on against armor plates have not been sufficiently numerous nor exact to allow of formula being deduced therefrom which we can rely upon as being under all circumstances absolutely accurate. Such formula as those given below prove, however, very useful, not only for the purpose of comparing the penetration or perforating power (at any particular range) possessed by projectiles of different pieces, but also as allowing us to calculate approximatively what this power will be.

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* Looking at the projectile as a cylinder of mass M, and radius $\frac{d}{2}$.

† For example, take the 10-inch rifle, where

I V = 1,364 f. s. $\quad = M\ 8\frac{W}{g} = \frac{400}{2240g}$ tons $\quad n = 40 \quad d = \frac{10}{12}$ ft. $\quad k^2 = \frac{d^2}{8}$

and

$$\frac{w^2}{2} M\, k^2 = \left\{ \frac{1364^2}{n^2\, d^2} (2\, \pi^2) \right\} \times \left\{ \frac{400}{2240g}\ \frac{d^2}{8} \right\}$$

which, when worked out, gives about 16 foot-tons of kinetic energy of rotation.

The formula for kinetic energy of translation is—
In foot-pounds

$$E = \frac{WV^2}{2g}$$

E = kinetic energy of translation of the projectile,
in which W = weight of projectile in pounds,
V = initial velocity in feet,
g = force of gravity (32.2).

This gives the energy in foot-pounds, the foot-pound being the blow struck by one pound falling through one foot, and to obtain it in foot-tons it is necessary to divide by 2,240, or the number of pounds in a ton; thus—
in foot-tons

$$E = \frac{WV^2}{2g \times 2240}$$

Formula for perforation of wrought-iron plates.

The formula of Capt. W. H. Noble, R. A., is—

$$t = \left(\frac{e}{2.52}\right)^{\frac{1}{1.6}}$$

t = thickness of plate shot can pierce.
e = kinetic energy per inch of shot's circumference $= \frac{WV^2}{2g\pi d\,2240}$
d = diameter of shot in inches.

The formula of Major Maitland, R. E., is—

$$t = \frac{E}{(14.87)\,r^2}$$

in which E = kinetic energy of translation of the shot $= \frac{WV^2}{2g\,2240}$
r = radius of the shot in inches.

This formula applies to the penetration of iron plates by chilled ogival-headed projectiles.

The formula of Captain Noble, which is merely a modification of the one deduced by Maj. A. Noble, F. R. S., was formerly used by the English in calculating tables showing the penetrating power of heavy guns. Latterly, however, the formula of Major Maitland has come into use.

The latter has considered the action of the ogival-headed projectile as a wedging rather than a punching action, and takes the sectional area instead of the circumference as used by Captain and Major Noble.

The experiments of Captain Von Doppelmair, of the Russian army, at Tegel, in the year 1868, showed that the previous calculations of the Russians, based on the assumption that the depth of penetration was proportional to the momentum of the projectile per square unit of cross-section, were fully confirmed by practice; while the figures obtained according to the English formula, based upon the assumption that the depth of penetration was proportional to the momentum per inch of circumference, were flatly contradicted.

Many of the experiments, on which Captain Noble's formula was based, were carried out with flat-headed projectiles, or with projectiles which upon striking the plate became such; which accounts sufficiently perhaps for

the disagreement between the results determined by his formula and those actually obtained in practice when chilled ogival-headed projectiles were employed.

REMAINING VELOCITY.

In the above formula, the depth of penetration is that which corresponds to the initial velocity, or the penetration at the muzzle of the gun. In order, therefore, to determine the penetration at any other given distance, we must first determine the remaining velocity—v, for that distance, which will be the velocity of impact, and substitute it for V in the values of E and e.

The formula for remaining velocity deduced by Professor Hélie is—

$$v = \frac{V}{1 + cVx}$$

in which v = the remaining velocity.

V = initial velocity.

x = distance from the muzzle in feet.

$c = b\frac{R^2}{W}$

R = radius of projectile in feet.

W = weight of p ectile in pounds.

b = a variable co-efficient depending on the form of the shot and its weight.

For the ogival form of head, and for velocities 1,100 feet, b may be supposed constant, and

$$b = 0.000063:$$

for velocities from 1,000 to 1,100 feet,

$$b = 0.000050,$$

and for velocities from 600 to 1,000 feet,

$$b = 0.000035.$$

DETERMINATION OF THE POSITION OF THE CENTER OF GRAVITY OF A GUN.

Regarding the gun as a solid of revolution whose axis coincides with that of the bore, the position of the center of gravity is determined from the principle that the sum of the moments of the weights of the several parts is equal to the moment of the weight of the entire piece. For convenience, the plane of reference is usually taken either at the knob of the cascabel and perpendicular to the axis of the bore, or as coincident with the front face of the piece.

The general formula expressing the above relation is—

$$W x = w^{i} x^{i} + w^{ii} x^{ii} + w^{iii} x^{iii} + w^{iv} x^{iv} + \&c.,$$

or

$$x = \frac{w^{i} x^{i} + w^{ii} x^{ii} + w^{iii} x^{iii} + w^{iv} x^{iv}}{W}, \qquad \text{(A)}$$

in which

W = the weight of the entire piece.

x = the distance of its center of gravity from the plane of reference.

$w^{i}\ w^{ii}\ w^{iii}$, &c. = the elementary weights; those corresponding to cavities (as the bore, chamber, &c.) being regarded as negative.

$x^{i}\ x^{ii}\ x^{iii}$, &c. = the distances of their respective centers of gravity from the plane of reference.

Should the gun be homogeneous throughout, the unit of weight may be canceled from the second member of equation (A), in which case it will be necessary to operate with the volumes simply, instead of the weights.

In guns of a curved exterior, like those of the Rodman model, it is customary to divide the gun up by a system of parallel planes, at right angles to the axis, and in numbers such that the elementary volumes thus formed shall closely approximate some regular geometrical figure, usually the conic frustum, of which the volume and the position of the center of gravity admit of ready calculation. When the gun is to be without preponderance, *i. e.*, when the axis of the trunnions is to pass through the center of gravity, the weights of the trunnions and rimbases may be omitted, since they will be symmetrically disposed about that axis.

PREPONDERANCE.

Where it is desired that the gun shall have a certain preponderance, the position of the axis of the trunnions in front of the center of gravity of the gun is determined as follows: The weight of the piece is supported by the elevating device and the trunnions. The pressure on the elevating device and its distance from the center of gravity are known; therefore the distance which the trunnions should be placed in front of the center of gravity to support the remainder of the weight will become known from the proportion—

$$p : (W - p) :: Y : l,$$

or,

$$Y = p \qquad l$$

in which p represents the preponderance; l the distance of the point of attachment of the elevating device from the center of gravity; $(W—p)$ the weight to be sustained by the trunnions; and Y the distance of their axis from the center of gravity.

APPROXIMATE DETERMINATION OF THE CENTER OF GRAVITY BY EXPERIMENT—METHOD BY DISTORTED SECTION.

(Plate LXV.)

A figure differing from a longitudinal half-section of the gun by the substitution in the place of the ordinates representing semi-diameters of those proportionate to the squares of the diameters, is cut from cardboard or other material of uniform weight for a given area. In this a point of suspension from which the axis assumes a horizontal position is readily found by trial, and its position relative to the length of the figure is the same as that of the center of gravity in the gun.

In the application of the method a convenient scale for the length of the gun and for abscissas in the line of its axis is one-tenth. For the ordinates it will usually be convenient to take one-hundredth of the square of semi-diameters.

The principles involved will hardly need explanation. *Areas* are made to correspond to volumes, and occupy the same relation to the center of gravity.

An extension of the plan gives a means of ascertaining approximately the *weight* of a gun. It will be found that the area of the figure drawn

on the scale proposed presents one square inch for every 3141.6 cubic inches of the volume of the gun. The area may conveniently be found by comparing the weight of the irregular piece of card-board with that of a carefully measured rectangular piece cut from the same sheet. The volume of the gun being found in cubic inches, the only remaining step to find its weight is, of course, to multiply by the weight per cubic inch.

Card-board of the better sort is commonly very uniform in weight in parts of the same sheet. This is especially so in parts lying in the direction of the length of the sheet in which the length of the figure should be made to conform.

The accuracy of the results will depend principally on the care and skill with which the method is applied.

The accompanying drawing will serve to illustrate the relation between the half-section of the gun and the figure to be used in determining the center of gravity.

Fig. 1 is on the scale of $\frac{1}{10}$, and Fig. 2 on the scale proposed above.

The dot surrounded by a small circle will represent the point of suspension from which the figure will take the position, bringing the axis to a horizontal line. Other dots near it may be supposed to represent points used in trial.

In the above determination the gun is supposed to be homogeneous, but when the case is otherwise, as in a gun built up of different metals, we first determine, in the above manner, the position of the center of gravity of each system of metals separately, and then combine the results for the center of gravity of the entire gun.*

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*Method proposed by Dr. Woodbridge and Captain André.

Tests of metals for cannon.

[Experiments of General Uchatius, of Austria.]

Weight in pounds per square inch of cross-section.	Cast iron from a 9-inch gun.		Bronze. Common from an 8-pounder gun.		Bronze. Cast in a chill. Natural state.		Bronze. Cast in a chill. Laminated.		Styrian wrought iron in small bars.		Krupp's steel from a 6-pounder gun.		Steel-bronze from near— The bore.		Steel-bronze from near— The outside.	
	Extension in one hundred-thousandth of its length.															
	Elastic.	Permanent.	Elastic.	Permanent.	Elastic.	Permanent.	Elastic.	Permanent.	Elastic.	Permanent.	Elastic.	Permanent.	Elastic.	Permanent.	Elastic.	Permanent.
1, 422	2	0	10	0	8	0	2	0	4	0	1	0	3	0	3	0
2, 844	10	0	15	0	15	0	7	0	9	0	3	0	5	0	14	0
4, 267	15	0	25	0	25	0	10	0	11	0	7	0	8	0	25	0
5, 689	22	0	35	0	40	0	22	0	14	0	12	0	14	0	35	0
7, 111	27	0	47	1	53	2	37	0	18	0	16	0	20	0	55	0
8, 534	33	0	56	4	62	4	50	0	22	0	20	0	26	0	65	0
9, 956	38	2	66	7	70	6	60	0	24	0	25	0	33	0	78	0
11, 378	47	4	77	11	79	8	73	0	27	0	30	0	40	0	86	3
12, 800	54	5	88	20	87	10	86	0	31	0	34	0	48	0	93	9
14, 223	61	6	101	32	100	13	96	0	35	0	39	3	54	0	103	12
15, 645	68	8	110	52	108	22	107	0	37	0	44	5	60	0	112	18
17, 067	76	10	120	96	115	47	117	0	40	2	50	7	66	0	129	26
18, 489	84	14	...	....	130	117	128	0	42	3	55	10	73	0	135	45
19, 912	92	19	....	....	150	327	139	0	45	4	60	14	80	0	160	125
21, 334	101	24	....	....	170	380	149	0	48	5	65	20	88	0	....	....
22, 756	110	30	....	....	192	441	159	0	52	6	71	31	96	0	....	....
24, 178	120	35	....	....	....	....	170	0	57	7	76	38	102	0	....	....
25, 601	130	50	....	...	....	....	179	2	62	8	81	48	110	0	....	....
27, 023	142	65	....	....	....	....	193	5	67	8	85	120	115	2	....	....
28, 445	157	81	....	...	...	....	205	8	72	9	90	252	121	3	....	...
29, 867	....	....	....	....	....	....	215	10	77	10	98	360	127	5	....	....
31, 290	....	....	....	....	....	....	222	12	82	12	110	586	134	7	....	....
32, 712	....	....	....	....	....	....	239	14	88	14	....	....	142	8	....	....
34, 134	....	....	....	....	....	....	252	18	93	16	....	....	152	10	....	....
Resistance to rupture per square inch	34, 419		32, 144		43, 380		72, 053		66, 847		68, 269		69, 336		46, 935	
Limit of elasticity ....lbs..	8, 534		5, 689		5, 689		24, 179		15, 645		12, 800		25, 601		9, 955	
Extension in hundredths of the length: elastic	0. 033		0. 035		0. 040		0. 170		0. 037		0. 034		0. 110		0. 075	
Extension in hundredths of the length: at moment of rupture	0. 40		15.		40.		2. 1		22.		21. 4		2. 5		40.	
Section at the point of rupture	0. 96		0. 66		0. 54		0. 96		0. 62		0. 50		0. 96		0. 58	
Hardness, length of cut. inches	. 402		. 492		. 492		. 402		. 413		. 413		. 413		. 472	
Number of blows of 86.7 foot pounds to break a bar 0.2 inches square	1.		1–10		....		....		....		209.		255.		146.	

Steel-bronze guns.

[Experiments of General Uchatius, of Austria.]

Physical properties.	Near the— Bore.	Near the— Outside.
Resistance to rupture, pounds per square inch	60, 447	47, 220
Limit of elasticity to a steady fall, pounds per square inch	15, 645	7, 111
Limit of elasticity to a blow, foot-pounds	2. 79	1. 33
Extension at rupture, in per cent. of its length	16. 5	0. 50
Extension elastic, in per cent. of its length	0. 306	0. 060
Section at point of rupture, the original section being = 1	0. 56	0. 50
Hardness (length of cut)	0. 417	0. 472
Number of blows of 86.8 foot-pounds to break a bar 0.2 inch square	1, 591	839

Table of results obtained by mandreling steel.

[From experiments of General Uchatius, of Austria.]

Substance submitted to fracture.	Resistance to rupture, pounds per square inch.	Limit of elasticity, pounds per square inch.	Elongations, in per cent. of the length. At rupture.	Elongations, in per cent. of the length. Elastic.	Hardness (length of cut in inches).
Bar of Krupp steel, 2.95 inches long, 0.775 square inch of section........	68, 130	12, 774	21. 5	0. 034	0. 423
Bar similar to the above subjected for 24 hours to a load of 1,650 pounds, producing an elongation 1.6 per cent......................	68, 130	28, 387	20	0. 160	......

Substance submitted to fracture.	Diameter. Exterior.	Diameter. Interior.	Resistance to rupture, pounds per square inch.	Limit of elasticity, pounds per square inch.	Elongations at rupture.	Elongations elastic.	Hardness (length of cut in inches).
Steel ring of same quality as above, mandreled twice:							
Before mandreling..	9. 429	6. 736	68, 130	12, 774	21. 5	0. 034	......
After mandreling ..	9. 498	6. 807	80, 419	28, 387	14	0. 110	......

Substance submitted to fracture.	Diameter. Exterior.	Diameter. Interior.	Resistance to rupture. Near the— Exterior.	Resistance to rupture. Near the— Bore.	Limit of elasticity. Near the— Exterior.	Limit of elasticity. Near the— Bore.	At rupture. Near the— Exterior.	At rupture. Near the— Bore.	Elastic. Near the— Exterior.	Elastic. Near the— Bore.	Hardness. In the bore.
Cylinder of very soft Newberg steel, mandreled seven times:											
Before mandreling .	9. 937	3. 086	59, 612		9, 935		26		0. 025		0. 445
After mandreling ..	9. 944	3. 228	70, 683	91, 122	14, 193	28, 587	25. 3	15	0. 111	0. 143	0. 420
Cylinder of medium Newberg steel, mandreled once:											
Before mandreling .	9. 940	3. 149	72, 955	90, 837	8, 516	17, 032	18	16	0. 030	0. 189	0. 382
After mandreling ..	9. 973	3. 179	72, 671	121, 780	11, 355	45, 677	16	8	0. 030	0. 354	0. 370

ENGLISH GUN-METALS.

Table showing the elastic limit and tenacity of average specimens of the metals used in the R. G. F.

Materials.	Tons per square inch at— Yielding.	Tons per square inch at— Breaking.	Elongation per inch at breaking.
Bronze	6.8	14.9	0.29
Cast iron. From	About 4	9.0	....
Cast iron. To		14.0	....
Wrought iron along its fiber	11.0	22 0	0.3
Steel. Soft	13.0	31.0	0.21
Steel. Tempered in oil	31.0	47.0	0.11

These numbers show, of course, only a rough average, approximating with reference to the particular natures of the metals mentioned which are used in the R. G. F.

ITALIAN BRONZE.

[Experiments of General Rosset.]

	Bronze guns. Common, cast in sand.	Bronze guns. Phosphor in chill.	Bronze guns. Common in chill.	Alloys melted in crucibles and cast in a chill. Phosphor bronze, No. 3.	Binary alloy. B L 9.	Binary alloy. B L 11.	N L 7/3.	N L 9/3.
Analysis of 100 parts of alloy:								
Tin	9.17	9.43	10.06	9.51	8.81	10.86	7.53	8.21
Zinc	....	....	....	0.56	....	....	2.97	1.04
Phosphorus	......	0.51	....	1.12	....	....	....	....
Total	9.17	9.94	10.06	11.19	8.81	10.86	10.50	9.25
Force of rupture on primitive section ..... pounds.	36,979	41,815	48,073	56,465	48,073	42,099	46,793	44,802
Ratio of section of rupture to primitive section ..... per cent	71	78	66	90	65	86	62	77
Limit of elasticity ..... pounds.	15,645	16,856	16,356	10,667	13,739	16,114	14,223	15,176
Elongation in thousandths to limit of elasticity	0.96	1.08	0.95	0.78	0.90	1.00	1.00	1.00
Co-efficient of elasticity	11,458	10,645	11,648	9,806	10,733	11,330	10,000	10,359
Apparent density	8.86	8.30	8.53	8.40	8.89	8.87	8.85	8.82
Empty space, per cent. of the mass	6.26	3.68	3.62	1.74	0.11	0.22	1 36	1.40
Hardness	2.50	5.22	5.35	6.9	5.53	4.87	5.37	6.27
Limit of cohesion ..... pounds.	17,067	19,201	19,201	....	18,490	19,912	17,067	17,067

Physical properties of low and medium steel.

	Whitsworth's fluid compressed (medium).	Krupp's (low).	Bochum (low).	Firth (medium).	Creusot (medium).	American. Midvale (low).	American. Midvale (medium).	American. Nashua chrome steel, Martin Simmons (low).
Density	7.855	....	7.8484 / 7.8634 (?)	....	......	7.8682	7.8462	......
Absolute tenacity	110,000	....	....	....	......	....	110,000	......
Ultimate resistance to pulling stress	86,000	68,129	57,000 to 72,000	74,000 to 80,000	88,000	67,000	89,000	65,000
Elastic limit under pulling stress	38,500	12,774	18,000 to 23,000	41,000 to 48,000	51,000	33,000	49,000	......
Elongation:								
Ultimate	0″.17500	0″,215	0″.1385 to 0″.0765	0″.17 to 0″.13	0″.14	....	0″.0021	0″.27
Elastic	0″.00230	0″.0034	0″.00065 to 0″.00083	....	......	0″.260	0″.19	......
Hardness	16.2	....	12.14	....	......	....	18	......

Relative properties of metals in general.

TABLE OF TENACITY.

Lead	1
Tin	$1\frac{1}{8}$
Zinc	2
Palladium	$11\frac{1}{2}$
Gold	12
Silver	$12\frac{1}{2}$
Platinum	15
Copper	18
Iron	$27\frac{1}{2}$
Steel	42

TABLE OF MALLEABILITY.

1. Gold.
2. Silver.
3. Copper.
4. Tin.
5. Platinum.
6. Lead.
7. Zinc.
8. Iron.

TABLE OF DUCTILITY.

1. Gold.
2. Silver.
3. Platinum.
4. Iron.
5. Copper.
6. Palladium.
7. Aluminum.
8. Zinc.
9. Tin.
10. Lead.

TABLE OF SPECIFIC GRAVITIES OF METALS.

Platinum	$21\frac{1}{2}$	21.53
Gold	$19\frac{1}{3}$	19.34
Mercury	$13\frac{3}{5}$	13.59
Palladium	$11\frac{4}{5}$	11.8
Lead	$11\frac{1}{3}$	11.36
Silver	$10\frac{1}{2}$	10.53
Bismuth	$9\frac{4}{5}$	9.79
Copper	9	8.95
Nickel	$8\frac{4}{5}$	8.82
Iron	$7\frac{4}{5}$	7.84
Tin	$7\frac{1}{3}$	7.29
Zinc	$7\frac{1}{7}$	7.14
Antimony	$6\frac{2}{3}$	6.71
Aluminum	$2\frac{2}{3}$	2.67
Magnesium	$1\frac{3}{4}$	1.74

TABLE OF CONDUCTING POWER FOR HEAT.

1. Silver.
2. Gold.
3. Copper.
4. Aluminum.
5. Zinc.
6. Iron.
7. Tin.
8. Platinum.
9. Lead.
10. Antimony.
11. Bismuth.

TABLE OF CONDUCTING POWER FOR ELECTRICITY.

Silver = 1000.

Copper	999
Gold	779
Zinc	290
Palladium	184
Platinum	180
Iron	168
Nickel	131
Tin	123
Lead	83
Antimony	46
Bismuth	13

TABLE OF FUSIBILITY.

	Melts at—
Tin	442° Fahr.
Cadmium	442
Bismuth	507
Lead	617
Zinc	773
Antimony*	1,150
Silver	1,800° Fahr.
Copper	1,990
Gold	2,000
Cast iron	2,780
Steel	4,000
Wrought iron	4,000

* Estimates of temperature above the fusing point of zinc cannot be regarded as exact, on account of the difficulty of ascertaining them.

Platinum melts only in the oxy-hydrogen blow-pipe flame.
The above tables are from Professor Bloxam's work on metals.

Table showing percentage of velocity realized and energy per pound of powder with United States service guns using maximum battering charges.

Nature of piece.	Bore.		Charge.			Projectile.	Gas.	Velocity.			Energy per pound of powder.		
	Diameter.	Length.	Nature.	Weight.	Weight per cubic inch.	Weight.	Total volume in bore.	Actual.	Calculated.	Percentage realized.	Actual.	Calculated maximum.	Percentage realized.
	Inches.	*Calibers.*		*Lbs.*	*Lbs.*	*Lbs.*		*Feet.*	*Feet.*		*Foot-tons.*	*Foot-tons.*	
12.25-inch rifle	12.25	18.53	Hexagonal	110		700	9.393	1,403	1,541	91.18	86.83	104.8	82.85
12-inch rifle, model 1870	12	17.41	....do	100	.03862	600	9.125	1,310	1,579	82.96	71.82	103.8	69.17
10-inch rifle	10	15.85	....do	80		400	6.009	1,430	1,612	88.71	70.87	90.15	78.61
8-inch rifle	8	14.66	....do	35	.03818	180	6.434	1,414	1,610	87.83	71.71	92.4	77.6
4.5-inch rifle	4.5	26.67	Cannon	7	.0361	35	9.842	1,420	1,748	81.23	71.88	106.1	67.74
3.5-inch rifle	3.5	18.57	New mortar	3	.0373	16.75	7.779	1,314	1,596	82.33	66.66	98.9	67.40
3-inch rifle	3	21.66	....do	2		10	8.566	1,418	1,718	82.53	69.7	102.4	67.09
20-inch smooth-bore gun	20	10.50	Mammoth	200	.0355	10.80	11.71	....	....	....	....	111.6	....
15-inch smooth-bore gun, model 1861	15	11	Hexagonal	125	.03818	450	8.906	1,735	2,036	85.21	75.59	103.5	73.03
13-inch smooth-bore gun	13	11.98	Mammoth	70	.0355	300	10.481	1,557	1,907	81.64	76.24	108.1	70.52
10-inch smooth-bore gun	10	12	....do	25	.034	128	12.893	1,500	1,795	83.56	79.84	114.4	69.90
8-inch smooth-bore gun	8	13.75	....do	10		65	18.71	1,400	1,671	83.78	88.32	125.78	70.21
12-pounder smooth-bore gun	4.62	13.76	Mortar	2.5	.0306	12.3	13.043	1,495	1,832	81.59	76.24	114.5	66.58

Tables of comparative power of American and European heavy rifled ordnance.

Kind of gun.	Caliber.	Weight of guns.	Length of bore.	Charge of powder.	Weight of shot.	Muzzle velocity.	Pressure per □″ of bore.	Energy per inch of shot's circumference at— Muzzle.	1,000 yds.	2,000 yds.	3,000 yds.	4,000 yds.
	Inches.	*Tons.*	*Inches.*	*Pounds.*	*Pounds.*	*Feet.*	*Pounds.*	*Ft.-tons.*	*Ft.-tons.*	*Ft.-tons.*	*Ft.-tons.*	*Ft.-tons.*
I.—12-INCH RIFLES.												
Armstrong breech-loader	12	38.89	264	179.6	697.5	1,614	41,587	....	....	....	....	....
English muzzle-loader (wrought-iron, steel tube)	12	35	162.5	110	700	1,300	52,864	217.7	184	157.5	136.4	124.9
Krupp breech-loader (steel)	12	35.30	227.167	110	664	1,329	29,106	215.8	180	152.6	130.9	113.6
Italian breech-loader (cast-iron, steel-hooped)	12.6	37	252	110	770	1,220	19,845	200.8	171.4	147.9	130.2	113.4
American muzzle-loader (cast-iron, wrought-iron tube)	12.25	40	227	110	700	1,403	31,750	248.4	205.8	173.2	147.9	127.7
II.—11-INCH RIFLES.												
English muzzle-loader (wrought-iron, steel tube)	11	25	145	85	535	1,315	....	185.7	154.1	130	111.1	96.1
Krupp breech-loader (steel)	11	27	207	88	495	1,410	....	188.7	159.4	131.3	110.1	93.7
French breech-loader (cast-iron, steel-hooped, and tubed)	10.803	21.7	163.7	79.38	476.4	1,378	....	184.9	149.8	123.9	104.1	88.7
American muzzle-loader (cast-iron, wrought-iron tube)	11	23.7	161	85	535	*1,359	....	198	163.7	137.4	116.9	100.7
III.—10-INCH RIFLES.												
English muzzle-loader (wrought-iron, steel tube)	10	18	145.5	70	400	1,364	47,040	164.3	132.9	109.7	92.9	78.4
Krupp breech-loader (steel)	10	19.44	169.6	66	374	1,426	....	167.9	132.7	107.5	88.6	74.6
Italian breech-loader (cast-iron, steel-hooped)	9.448	17	157.5	66	330	1,426.8	32,000	157	123.7	99.6	82.4	69.2
French breech-loader (cast-iron, steel-hooped, and tubed)	9.499	13.8	162.55	61.74	317.6	1,427	....	150	117	93.8	76.8	64
American muzzle-loader (cast-iron, wrought-iron tube)	10	18	147.22	70	400	†1,381	22,600	168.4	135.6	111.8	93.8	79.7
IV.—8-INCH RIFLES.												
English muzzle-loader (wrought-iron, steel tube)	8	9	118	35	180	1,413	....	99.2	73	56.1	44.5	36
Krupp breech-loader (steel)	8.26	9.7	161.8	37.4	216	1,384	....	110	84.6	66.9	54.1	44.7
French breech-loader (cast-iron, steel-hooped, and and tubed)	7.638	7.9	135.39	33.1	165.4	1,486	....	105.6	76.9	58.5	45.9	37.1
American muzzle-loader (cast-iron, wrought-iron tube)	8	7.66	117.25	35	180	1,414	29,423	99.4	73.2	56.2	44.5	36

NOTE.—In the above calculations R is taken = radius of bore. * Determined by calculation. † Velocity at 150 feet from gun.

Table of comparison between United States and European light siege rifles.

Nature of piece.	Caliber.	Weight.	Nominal exterior length.	Length of bore. Inches.	Length of bore. Caliber.	Rifling. Number of grooves.	Rifling. Twist. Caliber.	Rifling. Twist. Feet.	Powder. Kind.	Powder. Weight.	Projectiles. Kind.	Projectiles. Length.	Projectiles. Weight.	Ratio of weight. Of charge to weight of projectile.	Ratio of weight. Of weight of projectile to weight of piece.	Initial velocity.	Pressure per square inch of bore.	Muzzle energy, foot-tons. Total.	Muzzle energy, foot-tons. Per square inch of shot's cross-section.
	Ins.	*Lbs.*	*Ins.*							*Lbs.*		*Cal.*	*Lbs.*			*Feet.*	*Lbs.*		
Woolwich 40-pounder muzzle-loading rifle, steel-tubed.	4.75	3,920	114.75	104.5	22	3	Uniform. 35	13.8	W. A. R. L. G.	7	Studs.......	2½	40	1 to 5.7	1 to 98	1,399 1,380	59,480	542.7	30.6
Armstrong, 40-pounder breech-loading rifle, French breech mechanism.	4.75	2,904	112	104.5	22	27	Increasing to 40	15.8	Pebble.	7¾ 8 8¼	Copper banded.	2½	32.94	1 to 4.25 1 to 4.11 1 to 3.98	1 to 87	1,496 1,542 1,548	17,540	542.9	30.6
Krupp, 12 centimeters breech-loading rifle.	4.72	3,124	115	102	21.5	18	Increasing to 63	25	Prismatic, 7 holes D. 1.64. Pebble, 0.5 & 0.63.	7 7.7	Copper banded.	2.8	36.3 38.5	1 to 5.1 1 to 5	1 to 87 1 to 81	1,542 1,542	......	593.3	33.9
United States 4.5 inch muzzle-loading rifle.	4.5	3,570	128	120	26.6	9	Uniform. 40	15	H. D. No. 3 H. D. No. 4 H. D. No. 4	7 7¼ 6 7 7	Absterdam sabot.	2.35	25 25 35	1 to 3.57 1 to 3.33 1 to 4.16 1 to 3.57 1 to 5	1 to 143 1 to 103	1,510 1,545 1,450 1,595 1,420	21,500 36,000 23,000 28,000 31,250	.... 451.1 503.2	.... 31.6

Cannon and ammunition of the United States Navy.

Kind of cannon.	Material.	Weight.	Preponderance.	Extreme exterior length.	Maximum diameter.	Minimum diameter.	Length of chamber and bore.	Rifling. Number of grooves.	Rifling. Width of grooves.	Rifling. Depth of grooves.	Rifling. Width of lands.	Rifling. Twist, one turn in—	Windage.	Charge.	Projectile. Shot.	Projectile. Shell, loaded and fuzed.	Initial velocity.	Elevation.	Range.
GUNS.																			
Smooth bores.		*Lbs.*	*Lbs.*	*In.*	*In.*	*In.*	*In.*		*In.*	*In.*	*In.*			*Lbs.*	*Lbs.*	*Lbs.*	*Feet.*	°	
20-inch muzzle-loader	Cast iron	96,000	3,000	198.0	64.0	35.9	157.0						0.2	200	1,080				
15-inch muzzle-loader*	....do	43,000	680	177.0	48.0	21.0	146.0						0.2	35		352	1,160	7	2,100
														100	440		1,560		
11-inch muzzle-loader*	....do	16,000	980	159.7	32.0	16.5	131.2					†	0.2	15		135.5	1,270	15	3,650
													0.15	20	166				
9-inch muzzle-loader*	....do	9,200	900	132.0	27.2	13.3	107.3					†	0.2	10		73.5	1,350	15	3,450
													0.15	15	90				
8-inch muzzle-loader*	....do	6,500	450	114.5	23.2	12.0	96.0						0.15	7		52.75	1,330	5	1,775
32-pounders (6″.4) muzzle-loaders*	....do	4,500	350	108.0	19.8	9.8	92.0						0.15	6		26.5	1,620	5	1,756
Rifles.																			
8″ (converted) muzzle-loader‡	Wrought-iron tube.	17,330	300	159.7	32.0	16.5	128.2	15	0.8377	0.075	0.8377	40′	0.05	20		180	1,270		
														35	§180		1,450		
6″.4 (converted) breech-loader‡	Steel tube			146.5	25.9	13.4	128.8	9	1.2566	0.10	1.2566	0 to 19′	0.05	10	80	80	1,250		
100-pounder Parrott (6″.4) muzzle-loader.‡	Wrought-iron jacket.	9,750		154.2	25.9	13.4	130.0	9	1.2566	0.10	4.2566	0 to 19′	0.05	10	100	96	1,250	30	7,810
60-pounder Parrott (5″.3) muzzle-loader.‡	....do	5,400		124.5	21.3	10.7	105.0	7	1.1931	0.10	1.1931	0 to 15′	0.04	6	60	50	1,200		
30-pounder Parrott (4″.2) muzzle-loader.‡	....do	3,500		112.2	18.3	8.6	96.8	5	0.9425	0.10	0.9425	0 to 12′	0.05	3.75	30	29		25	6,700
20-pounder Parrott (3″.67) muzzle-loader.‡	....do	1,800		91.3	14.5	7.2	79.0	5	1.1529	0.10	1.1529	0 to 10′	0.04	2.0	20	18		15	4,400
HOWITZERS.																			
Smooth-bores.																			
24-pounder (5″.82) muzzle-loader	Bronze	1,300	83	68.2	11.4	8.8	58.2						0.15	2	‖24	24		5	1,270
12-pounder heavy (4″.62) muzzle-loader.	....do	765	61	63.5	9.0	7.2	55.2						0.15	1	‖12	12		5	1,085
12-pounder light (4″.62) muzzle-loader.	....do	430	28	51.0	8.0	6.4	44.0						0.15	.625	‖12	12			

Rifles.																				
20-pounder (4″.0) breech-loader**	Bronze	1,340	....	67.0	11.4	7.0	53.3	6	Long, 2.08 Short, .68	0.08	0.68	12′.5	0.04	2	......	18	......	...	......
12-pounder (3″.4) muzzle-loader	....do	880	45	63.5	9.0	7.2	55.2	3	....	0.07	....	10′.0	0.04	1	......	12	......	5	1,770
3-inch heavy (2″.92) breech-loader	....do	500	2	60.2	8.8	4.9	55.4	16	††0.2941	0.04	††0.2941	6°	......	0.75	‖8	7	1,126	5	1,922
3-inch light (2″.92) breech-loader	....do	350	1.25	49.6	8.8	4.6	41.0	16	††0.2941	0.04	††0.2941	6°	......	0.75	‖8	7	1,099	10	2,948
Mortars.																			
13-inch smooth-bore muzzle-loader	Cast iron	17,000	....	54.0	36.0	.....	35.1	....	....	.....	....	....	0.15	20	......	200	......	45	4,200

* These guns have conical chambers, and are denominated "shell guns." More recent models of the 15-inch are semi-ellipsoidal at the bottom.

† When two numbers stand for windage, the larger refers to shot and the smaller to shell.

‡ Cast iron.

§ Battering shell.

‖ Shrapnel.

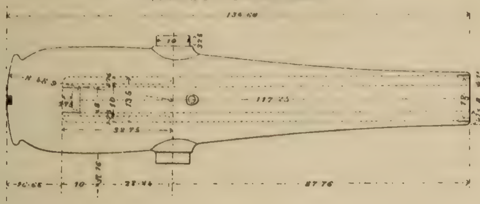
** This gun is the 20-pounder muzzle-loader converted to breech-loader for saluting purposes.

†† Measured at the base of the nib-radius, 1.50 inches; diameter of bore across faces of ribs, 2 92 inches; width of ribs at rear end, $\frac{2}{100}$ less than at muzzle.

SEA COAST CANNON. U. S. LAND SERVICE.

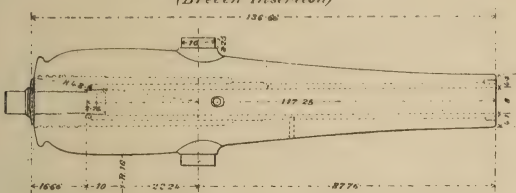
8 INCH RIFLE (CONVERTED)

(Muzzle Insertion)

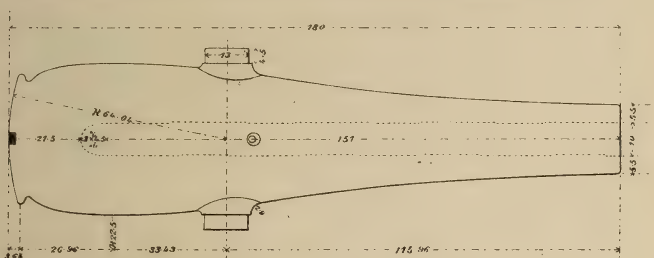


8 INCH RIFLE (CONVERTED).

(Breech Insertion)

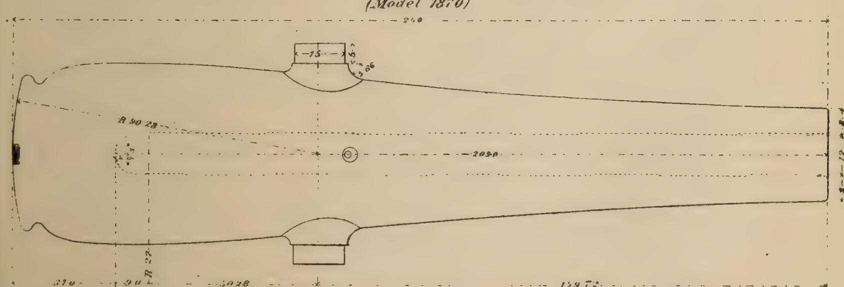


10 INCH CAST IRON RIFLE. {EXPERIMENTAL}

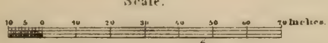


12 INCH CAST IRON RIFLE. {EXPERIMENTAL}

(Model 1870)

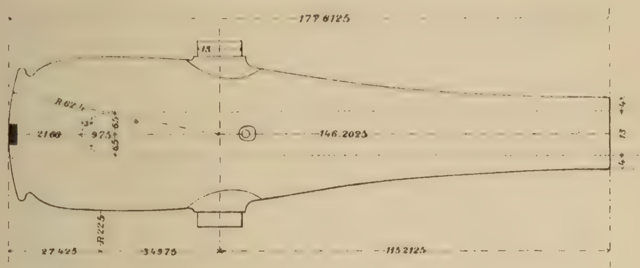


Scale.



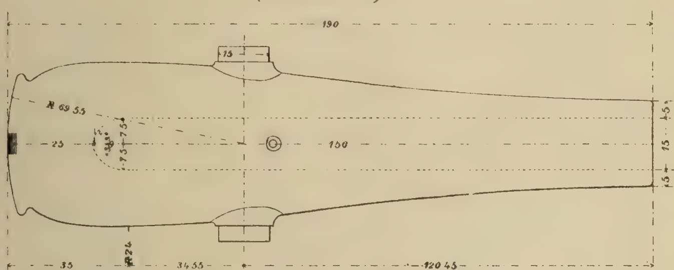
SEA COAST CANNON. U. S. LAND SERVICE.

13 INCH S. B. GUN.

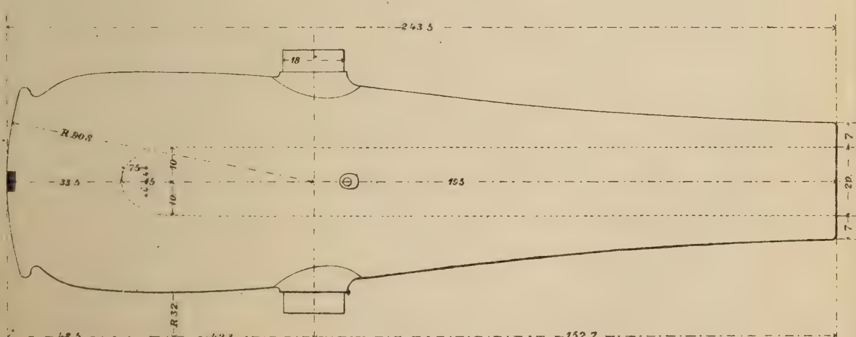


15 INCH S. B. GUN.

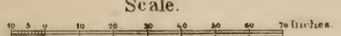
(Model 1861.)



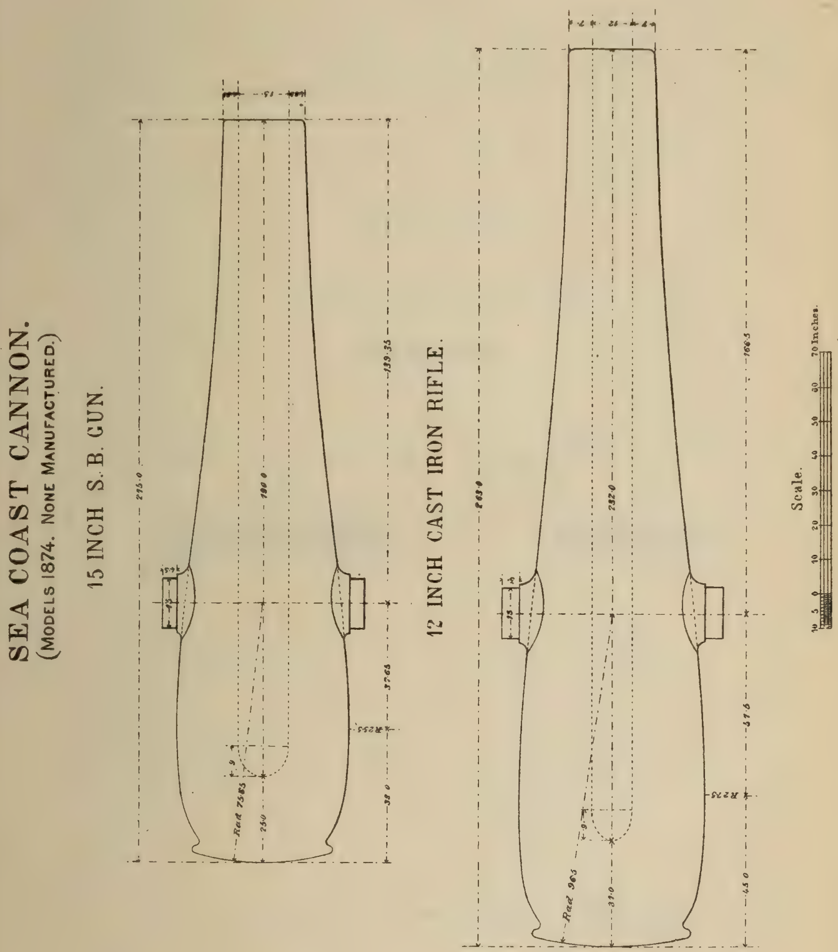
20 INCH S. B. GUN.



Scale.



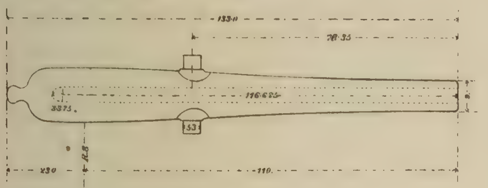
Appendix 9—1880.


SEA COAST CANNON.
(MODELS 1874. NONE MANUFACTURED.)
15 INCH S.B. GUN.
12 INCH CAST IRON RIFLE.
Scale.
70 Inches.

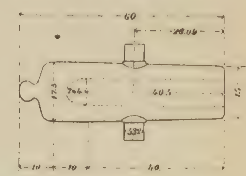
STANDARD CALIBERS. U. S. LAND SERVICE.

SIEGE PIECES.

4·5 INCH RIFLE.



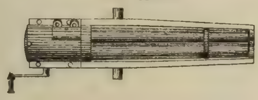
8 INCH S.B. HOWITZER.



FIELD PIECES.

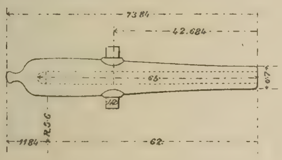
1·65 INCH HOTCHKISS B.L. RIFLE.

HOTCHKISS CANNON REVOLVER.
1·45 INCH.

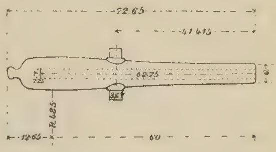


0.45 INCH RIFLE. B.L.GATLING

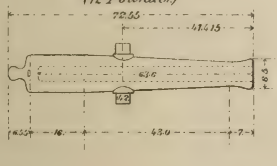
3.5 INCH RIFLE.



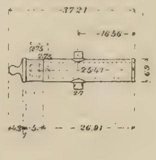
3 INCH RIFLE.



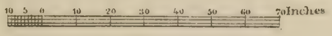
4.62 INCH S.B. GUN.
(12 Pounder.)



4.62 INCH S.B. MOUNTAIN HOWITZER.

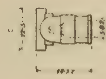


Scale.

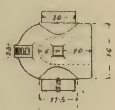


MORTARS. STANDARD CALIBERS. U. S. LAND SERVICE.

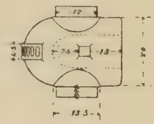
COEHORN.



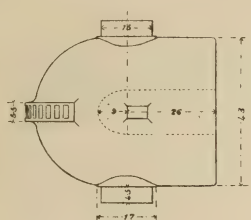
8 INCH SIEGE.



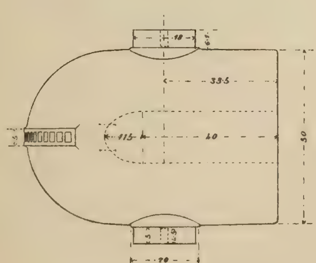
10 INCH SIEGE.



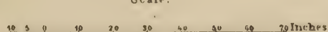
13 INCH SEA COAST.



15 INCH SEA COAST.



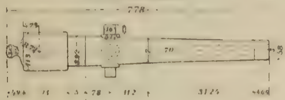
Scale.



RETAINED CALIBERS U. S. LAND SERVICE.

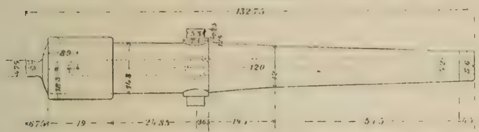
3 INCH PARROTT RIFLE. FIELD.

(10 Pounder)



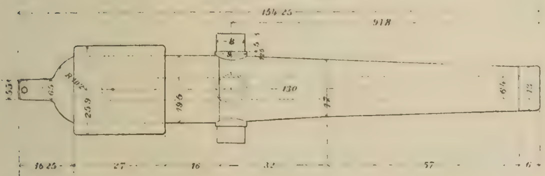
4.2 INCH PARROTT RIFLE. SIEGE.

(30 Pounder)



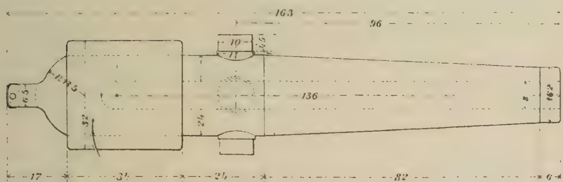
6.4 INCH PARROTT RIFLE. SEA COAST.

(100 Pounder)



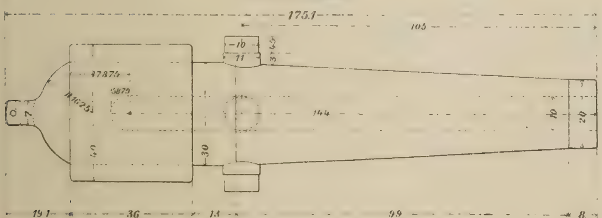
8 INCH PARROTT RIFLE. SEA COAST.

(200 Pounder)

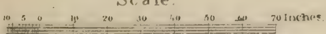


10 INCH PARROTT RIFLE. SEA COAST.

(300 Pounder)



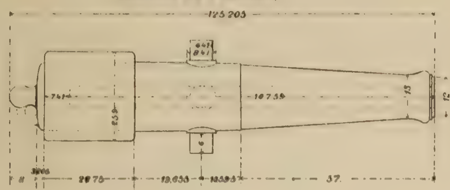
Scale.



RETAINED CALIBERS U. S. LAND SERVICE.

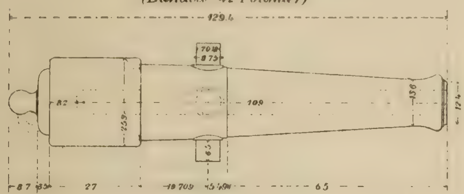
6.4 INCH RIFLE. SEA COAST.

(Banded 32 Pounder.)

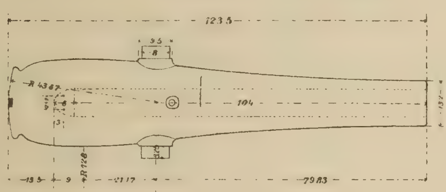


7.018 INCH RIFLE. SEA COAST.

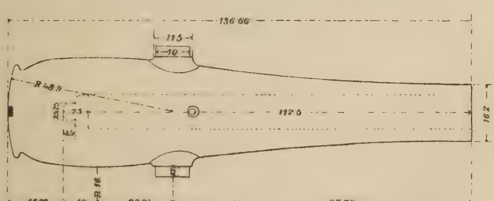
(Banded 42 Pounder)



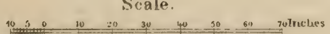
8 INCH S.B. RODMAN. SEA COAST.



10 INCH S.B. RODMAN. SEA COAST.



Scale.

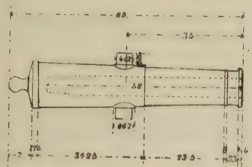


Appendix 9—1880.

RETAINED CALIBERS U. S. LAND SERVICE.

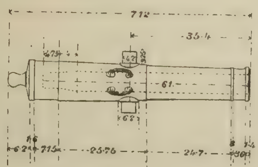
5·82 INCH HOWITZER. FLANK DEFENCE.

(24 Pounder.)



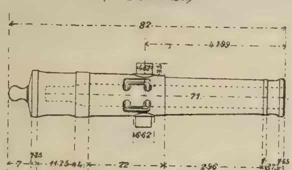
5.82 INCH HOWITZER. FIELD.

(24 Pounder.)

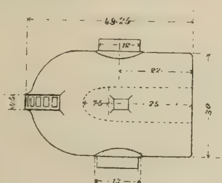


6·4 INCH HOWITZER. FIELD.

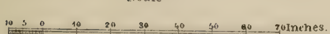
(32 Pounder.)

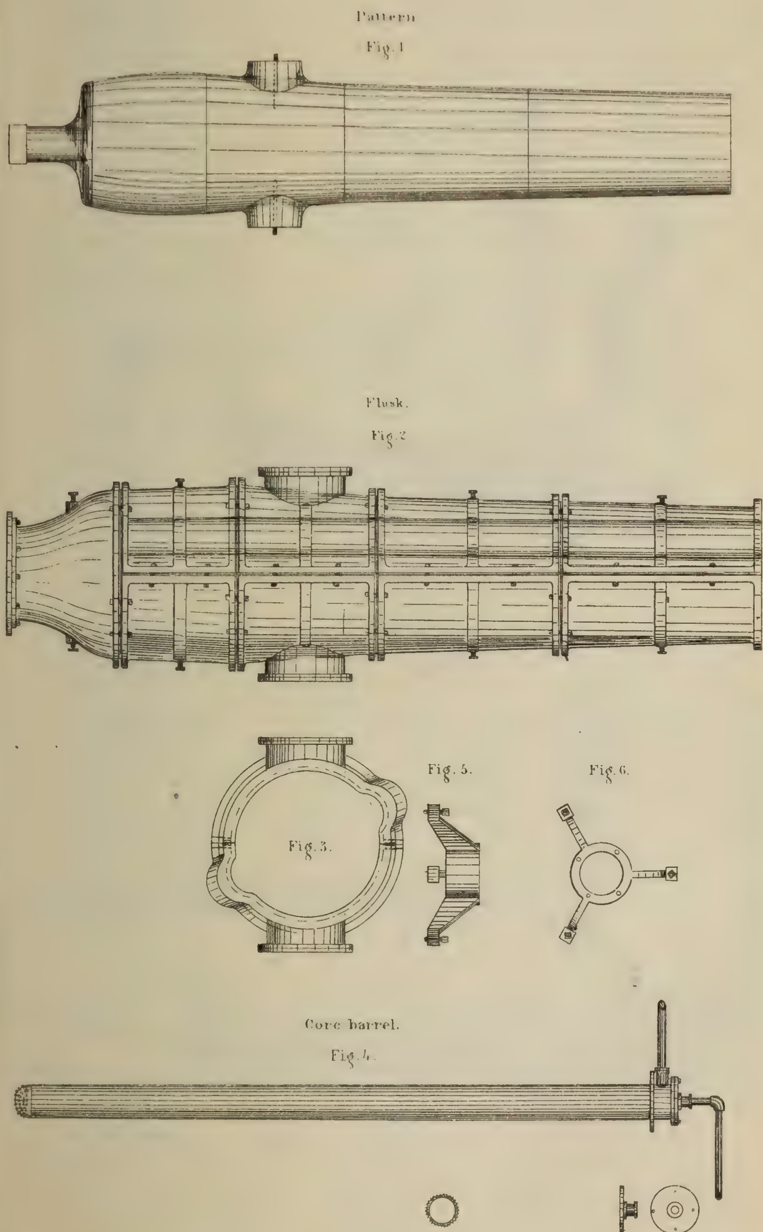


10 INCH MORTAR. SEA COAST.



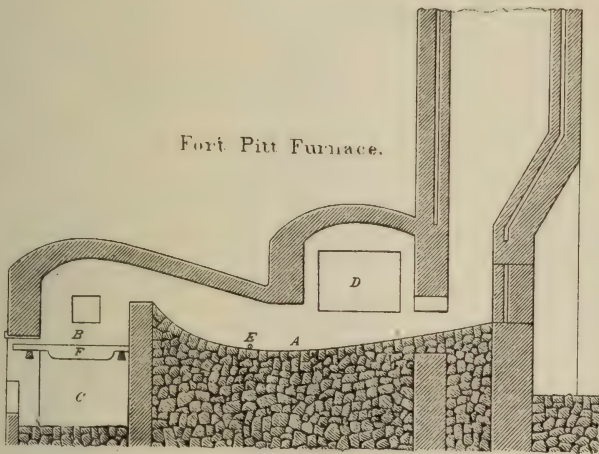
Scale



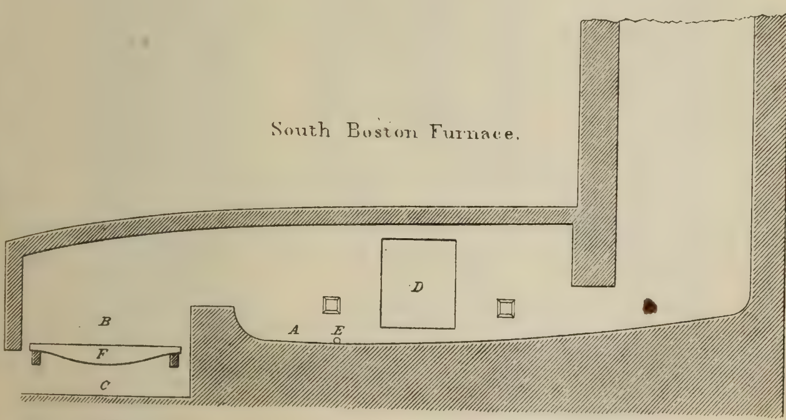

Pattern
Fig. 1
Flask.
Fig. 2
Fig. 3.
Fig. 5.
Fig. 6.
Core barrel.
Fig. 4.

AIR FURNACES.

Fort Pitt Furnace.



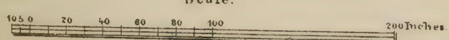
South Boston Furnace.



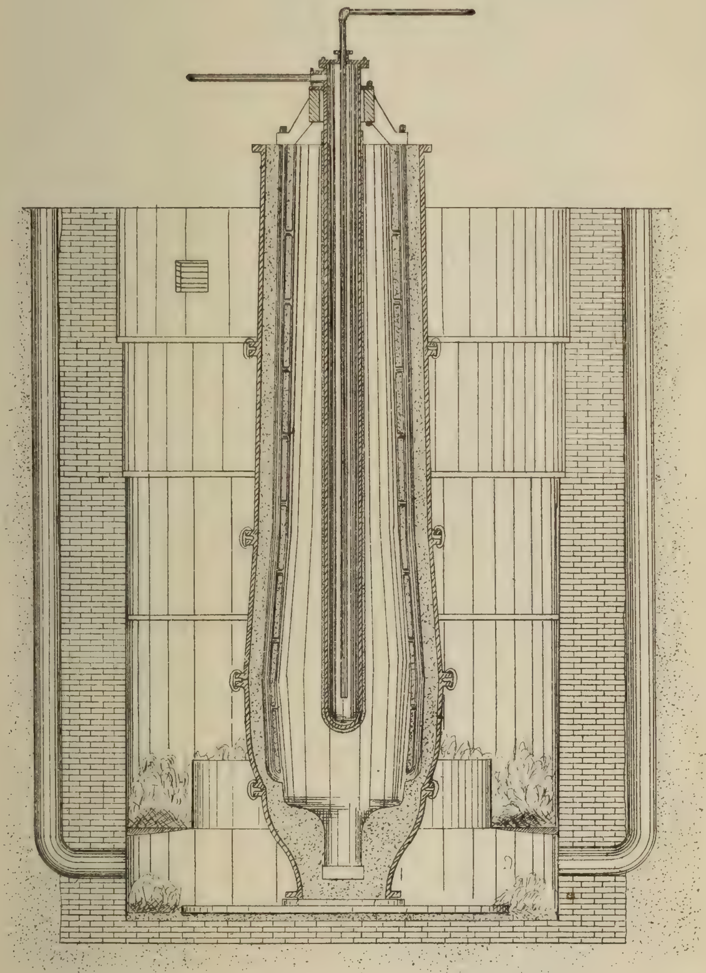
A. Metal chamber.
B, Fuel chamber.
C. Ash pit.

D. Charging door.
E. Tap hole.
F. Grate bars.

Scale.

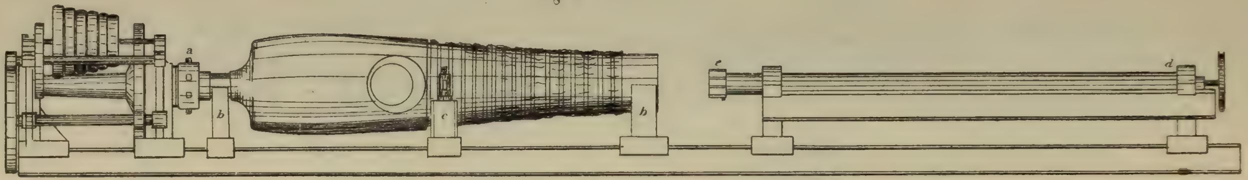


PIT AND MOULD READY FOR CASTING.



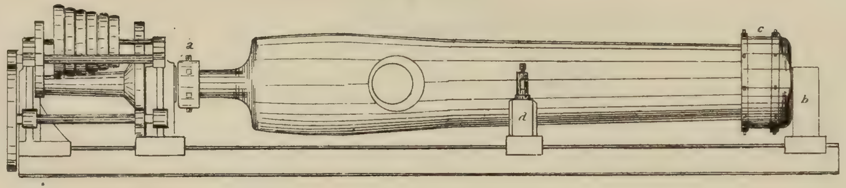
BORING LATHE.

Fig. 2.



HEADING LATHE.

Fig. 1.



Boring lathe.

a. *Chuck.*
bb *Bearings.*
c *Tool rest.*
d. *Boring rod.*
e. *Head.*

Heading lathe.

a *Chuck.*
b. *Bearing.*
c. *Bonnet.*
d *Tool rest.*

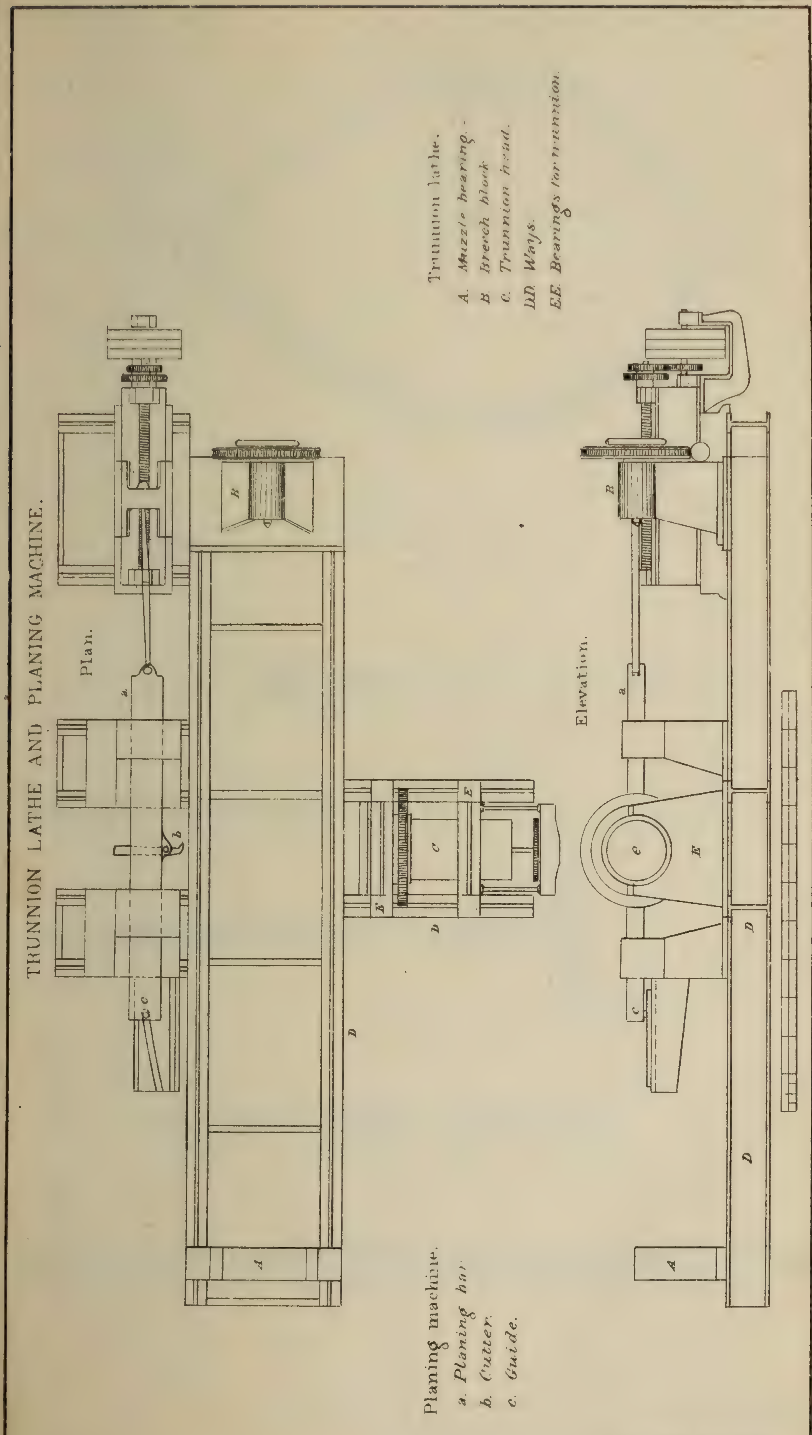
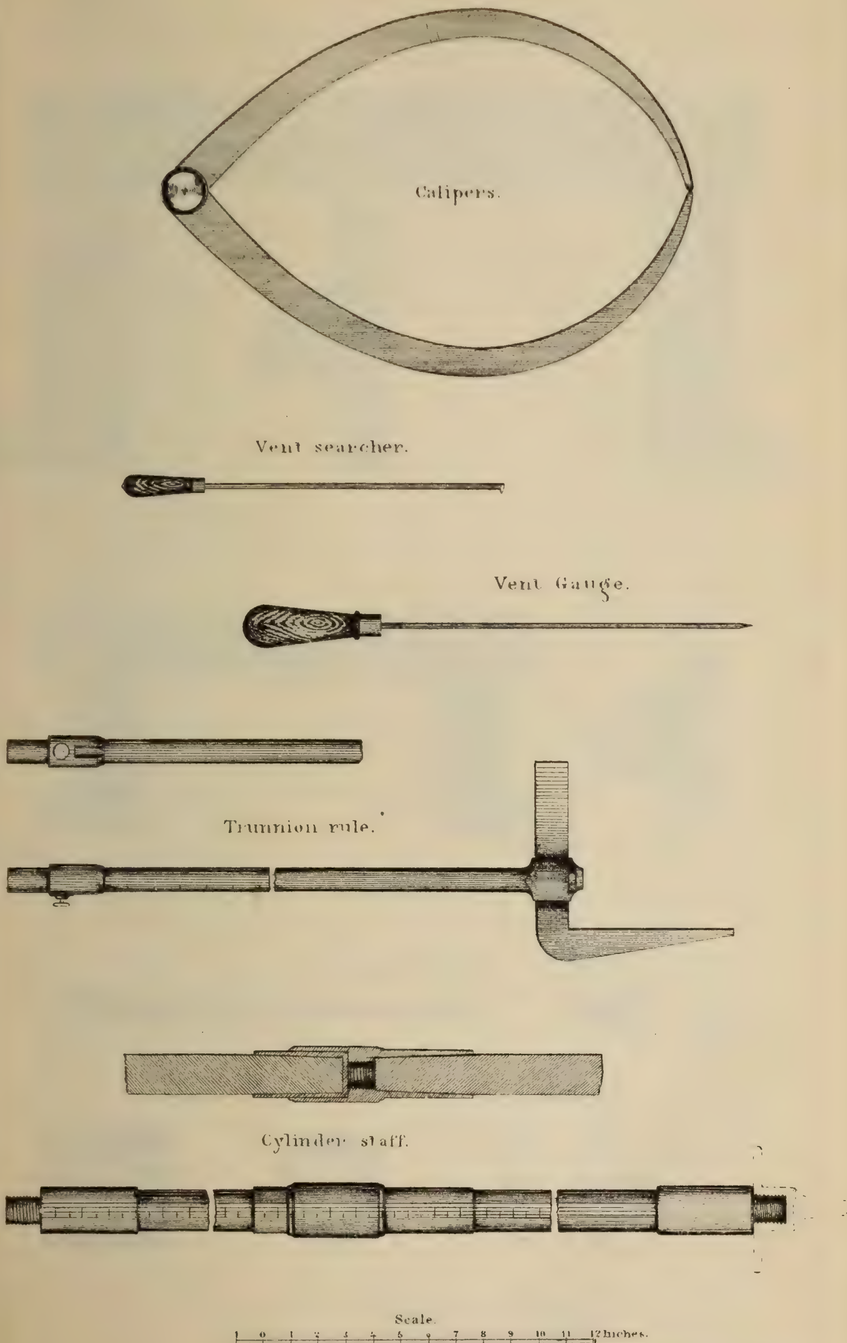
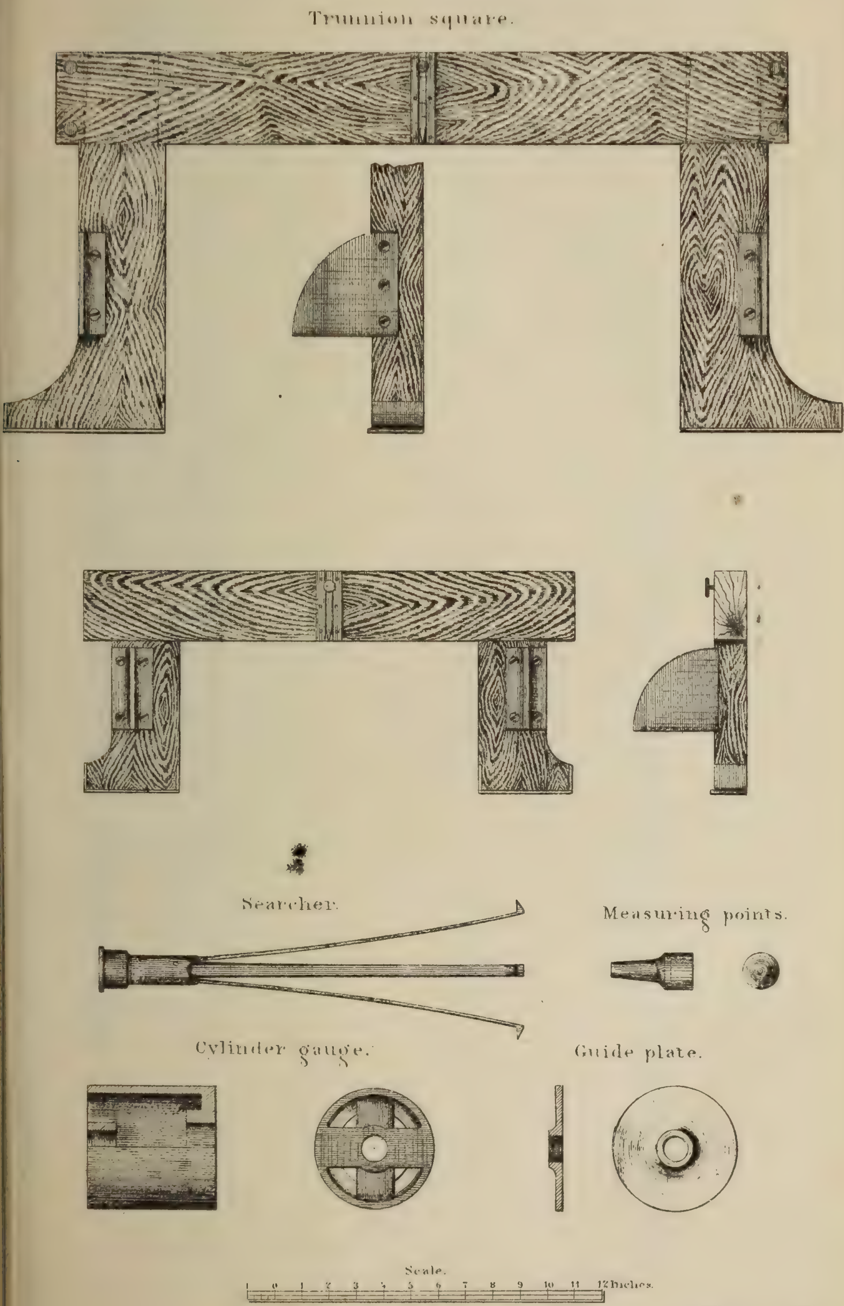

TRUNNION LATHE AND PLANING MACHINE.
Plan.
Elevation.
Trunnion lathe.
A. Muzzle bearing.
B. Breech block
C. Trunnion head.
DD. Ways.
EE. Bearings for trunnion.
Planing machine.
a. Planing bar
b. Cutter.
c. Guide.

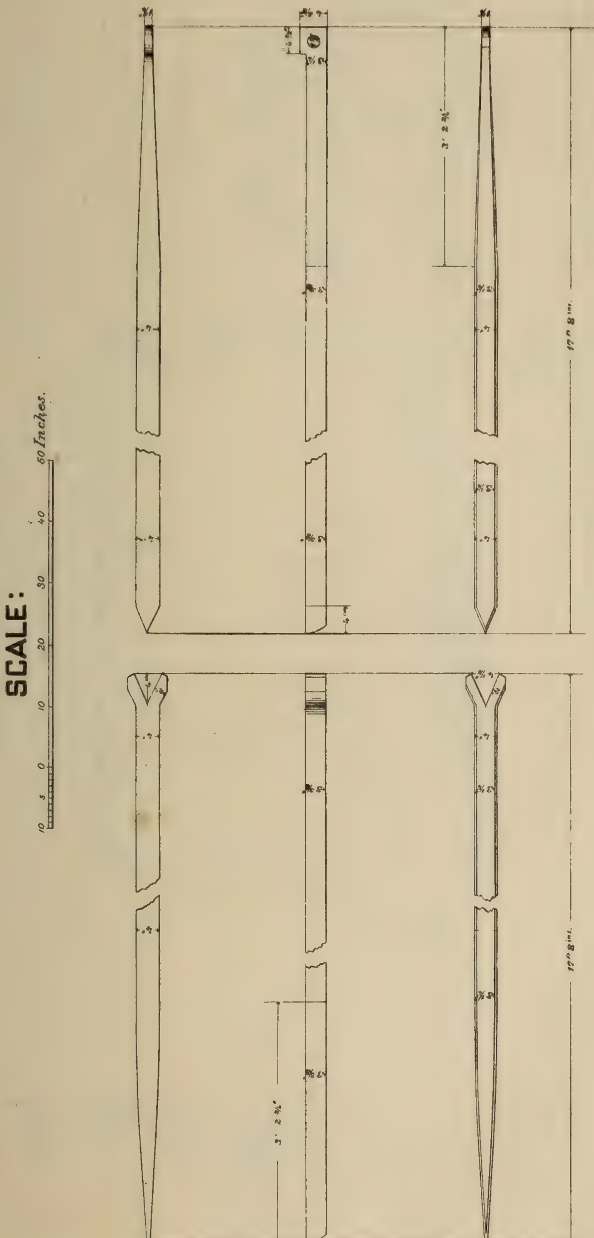
PLATE XIV.

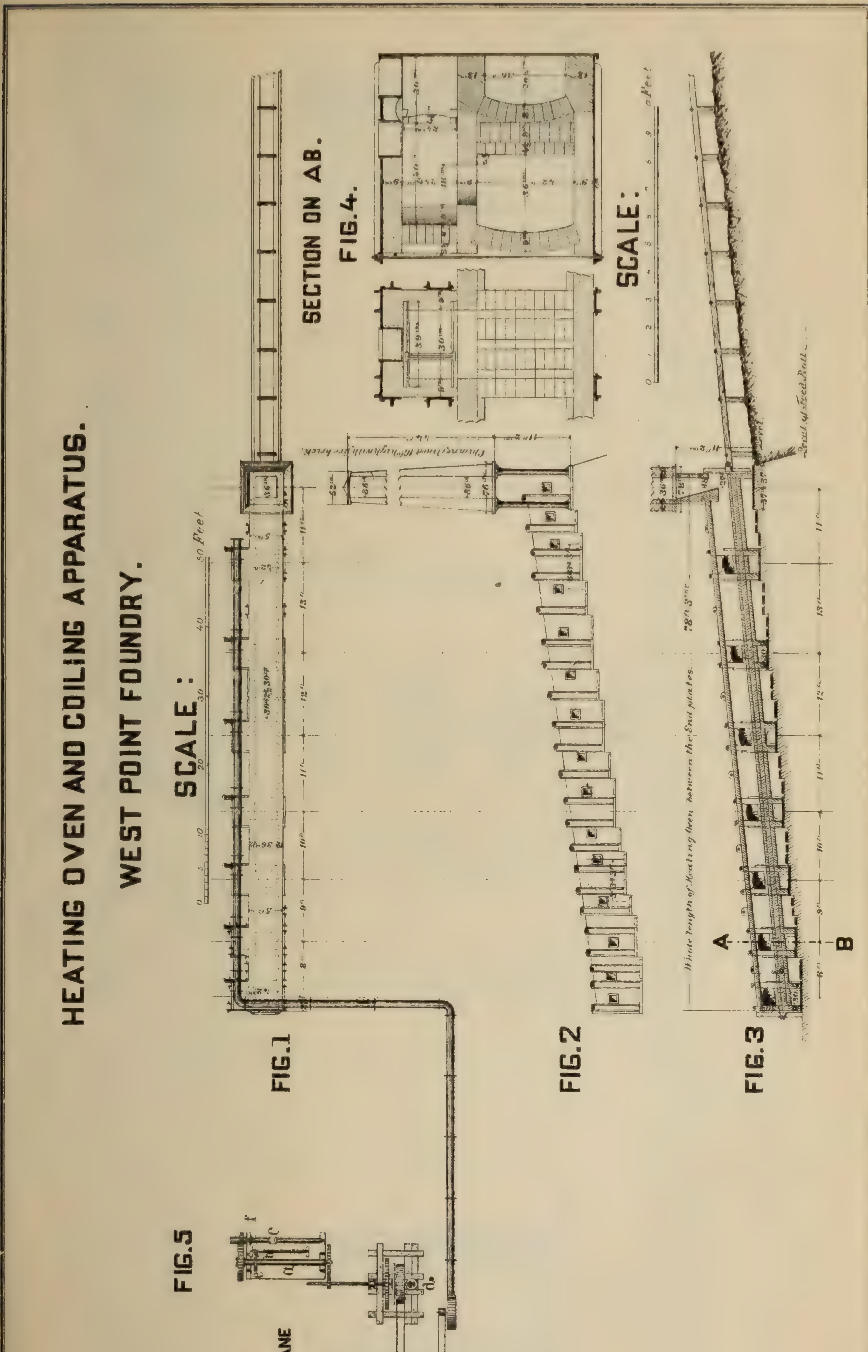


Appendix 9—1880.


Trunnion square.
Searcher.
Measuring points.
Cylinder gauge.
Guide plate.
Scale.
1 0 1 2 3 4 5 6 7 8 9 10 11 12 Inches.

BARS PREPARED FOR SCARFING AND END-WELDING.




HEATING OVEN AND COILING APPARATUS.
WEST POINT FOUNDRY.
SCALE :
50 Feet.
FIG.1
FIG.2
FIG.3
SECTION ON AB.
FIG.4.
SCALE :
FIG.5
STEAM CRANE
A
B
Level of Feed Roll

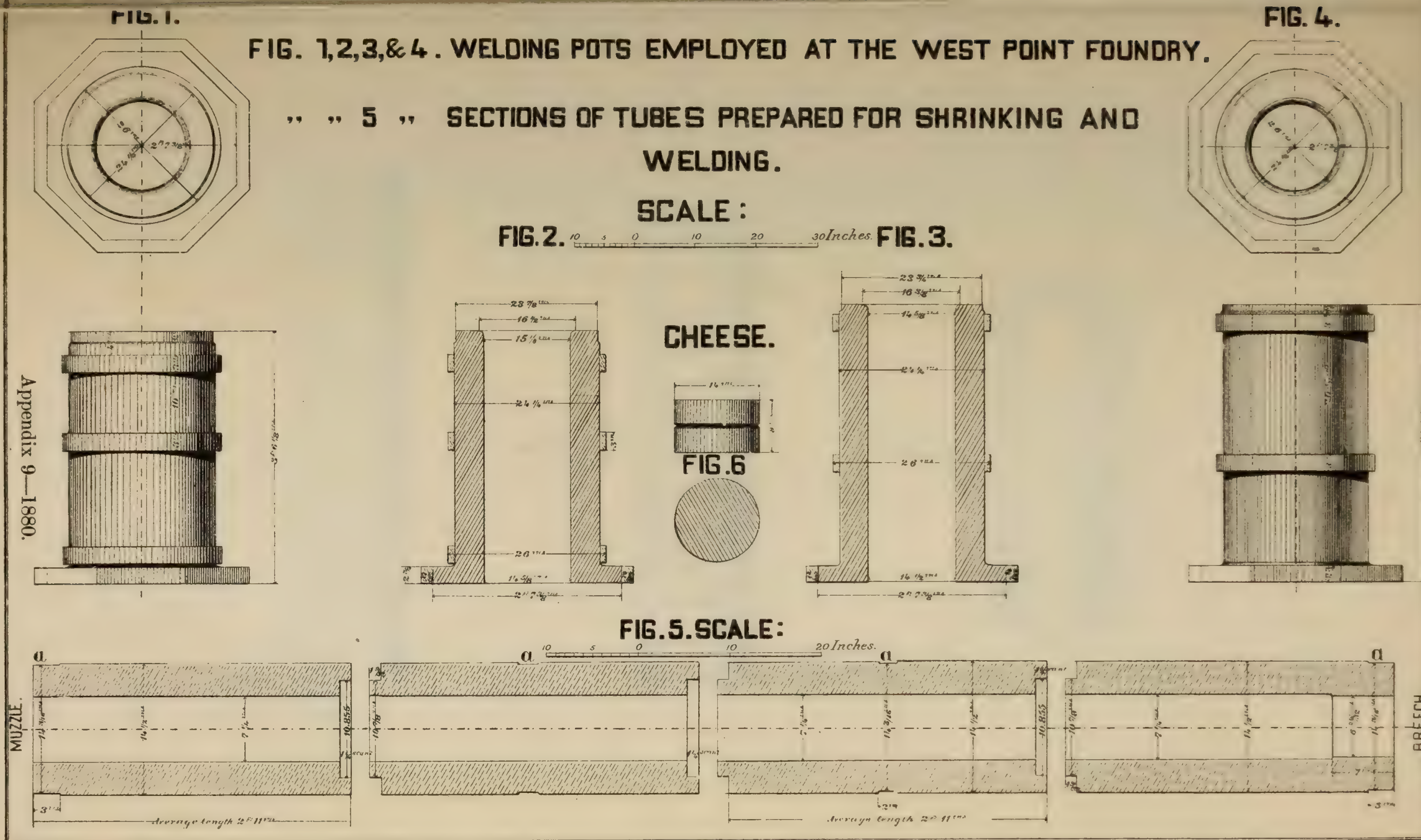


FIG. 1, 2, 3, & 4. WELDING POTS EMPLOYED AT THE WEST POINT FOUNDRY.

" " 5 " SECTIONS OF TUBES PREPARED FOR SHRINKING AND WELDING.

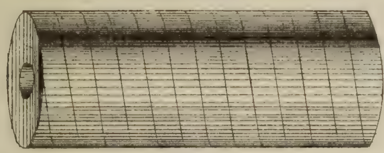


FIG. 3.

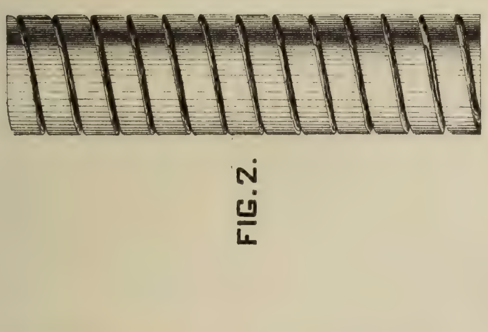


FIG. 2.

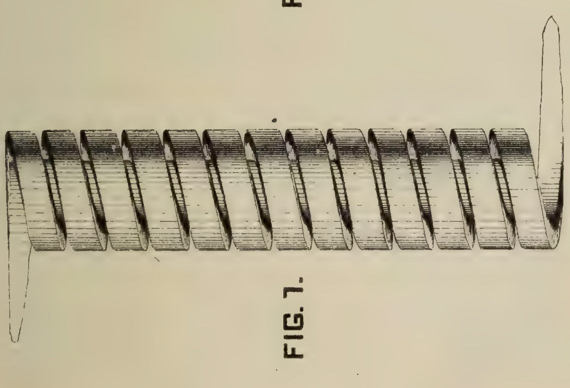
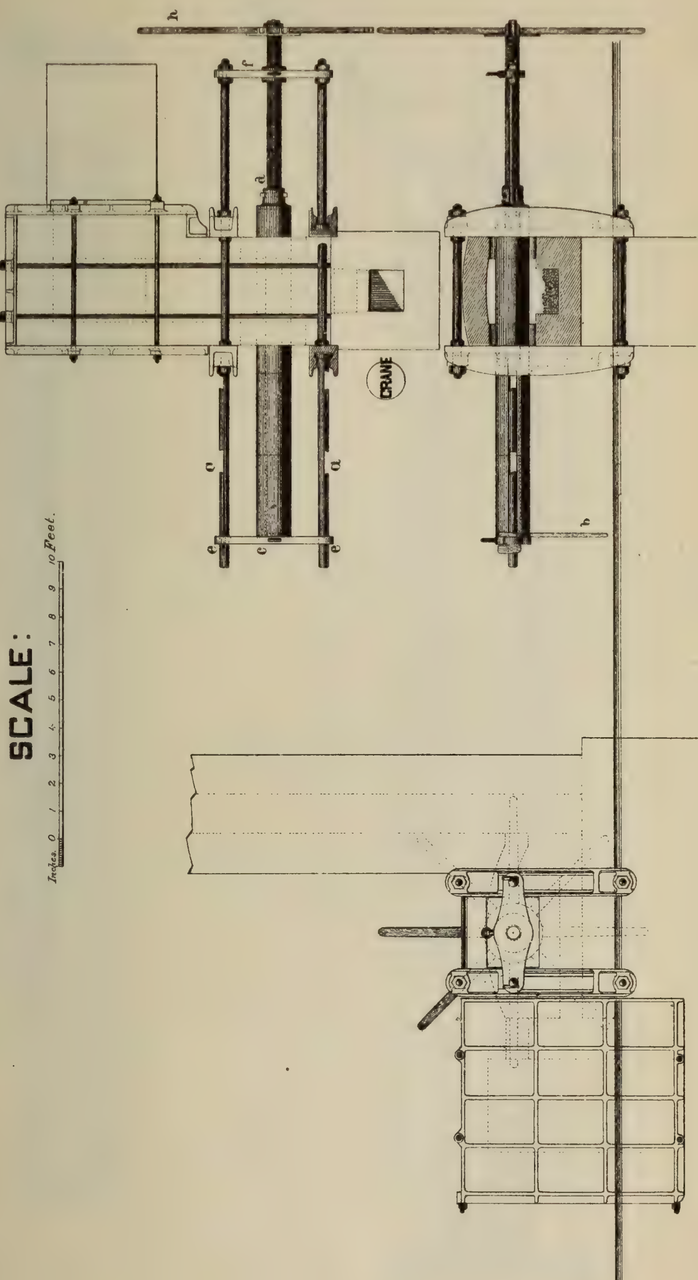
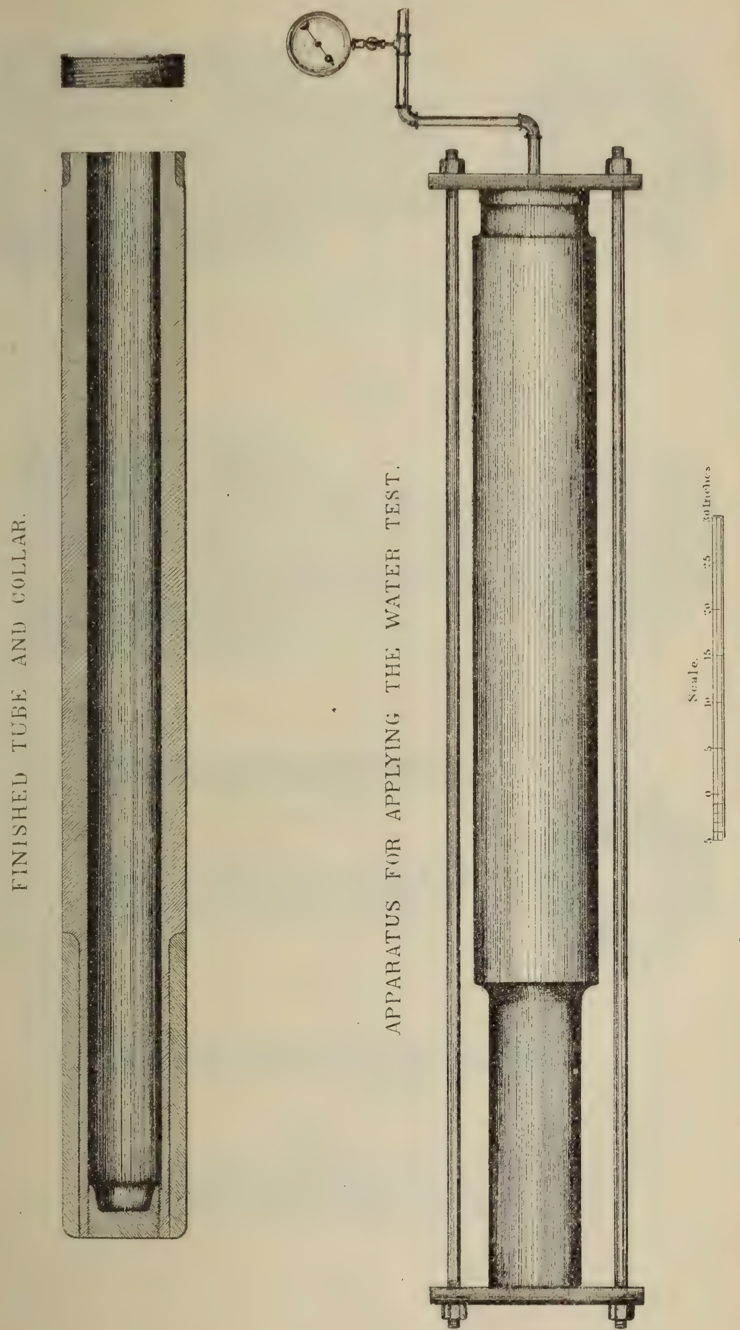


FIG. 1.

METHOD OF WELDING SECTIONS AT THE WEST POINT FOUNDRY.



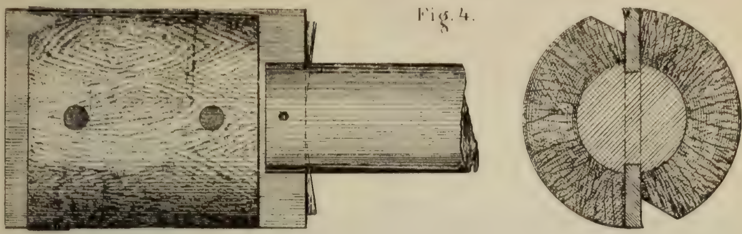


FINISHED TUBE AND COLLAR.

APPARATUS FOR APPLYING THE WATER TEST.

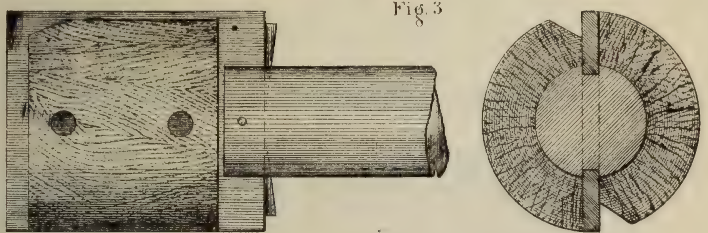
Fine boring tool.

Fig. 4.



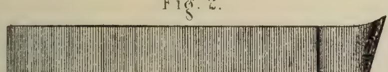
Rough boring tool.

Fig. 3



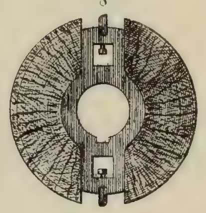
Fine cutting tool.

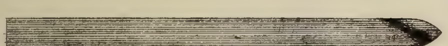
Fig. 2.



Boring head

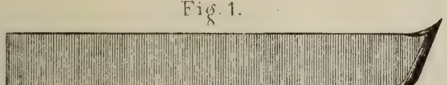
Fig. 5.

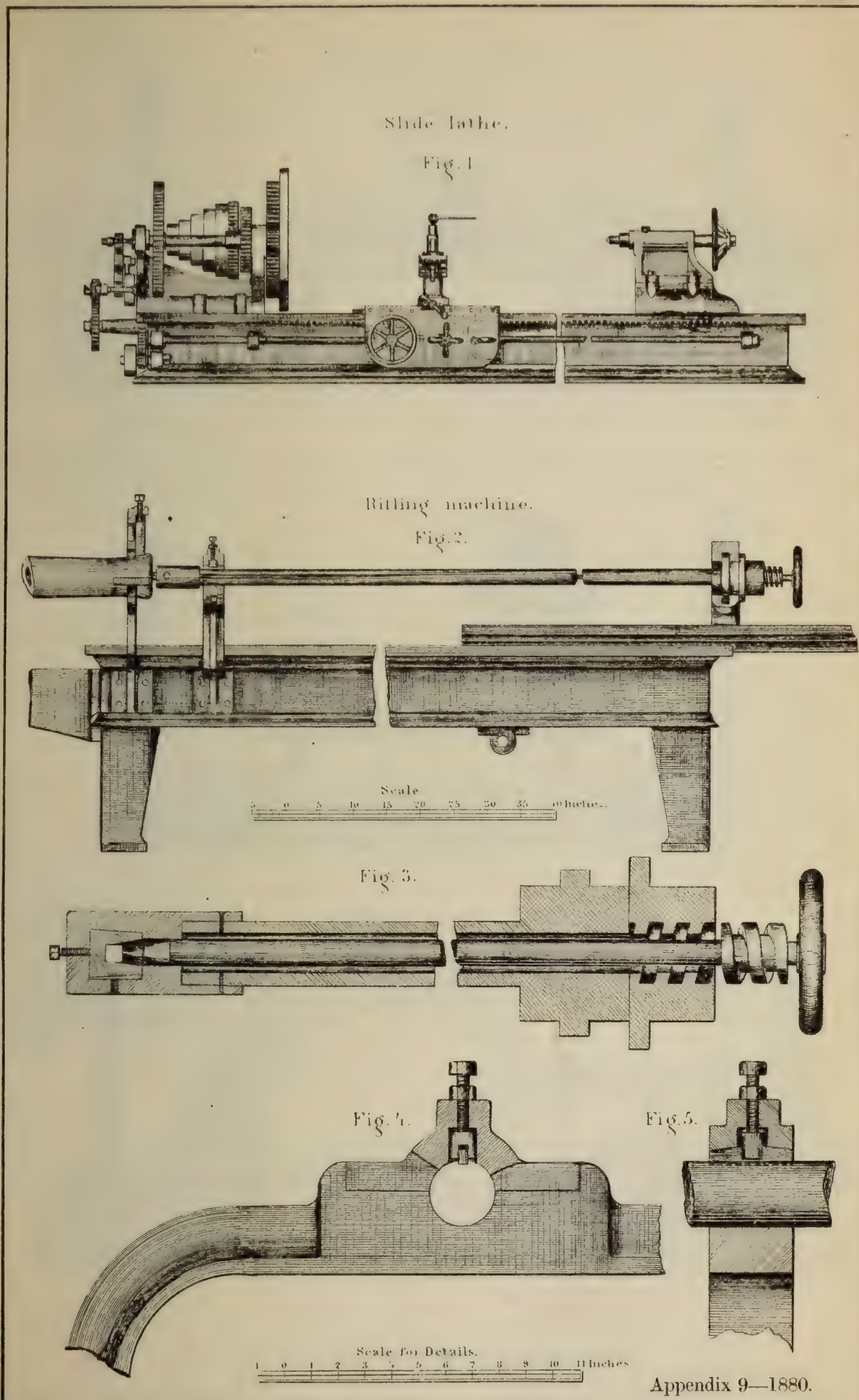




Rough cutting tool

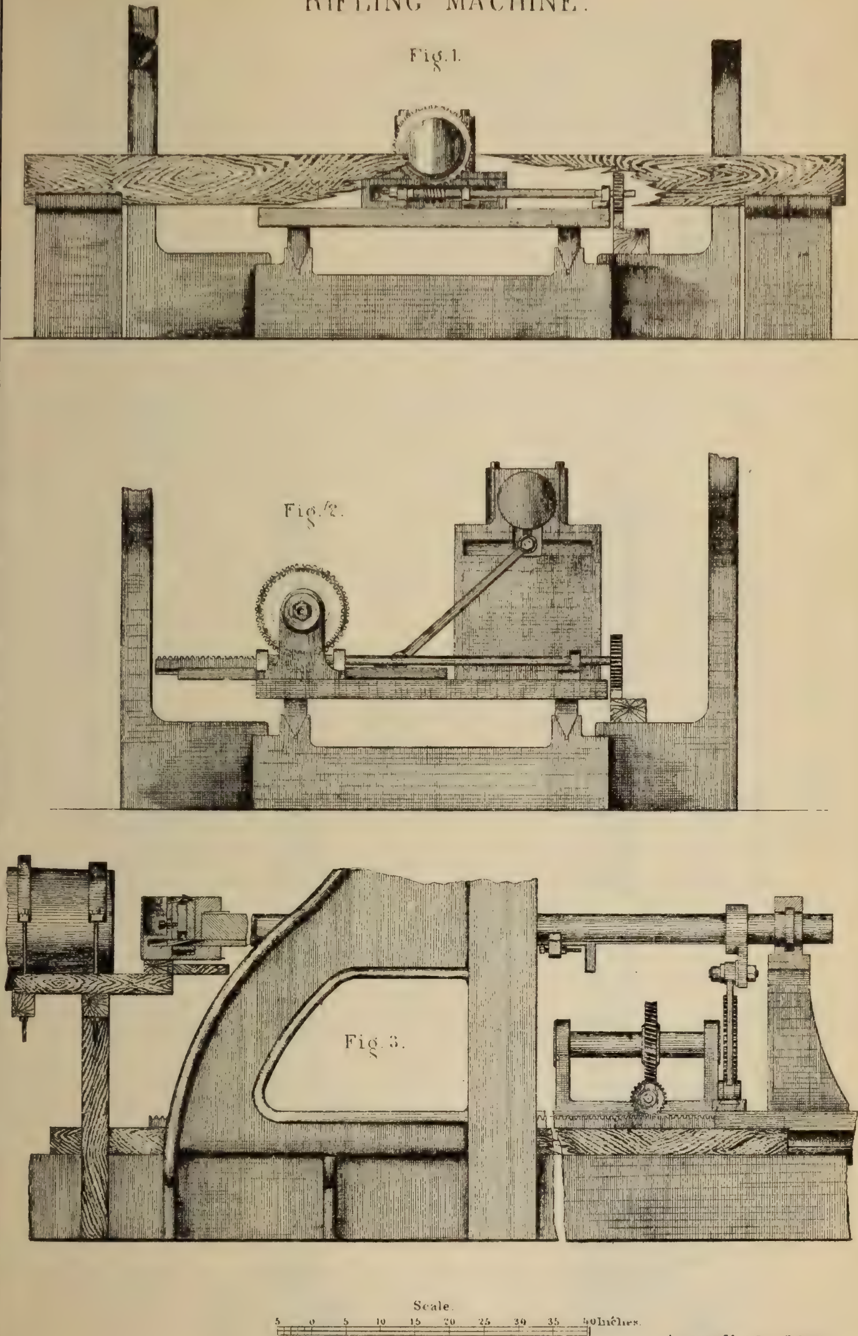
Fig. 1.



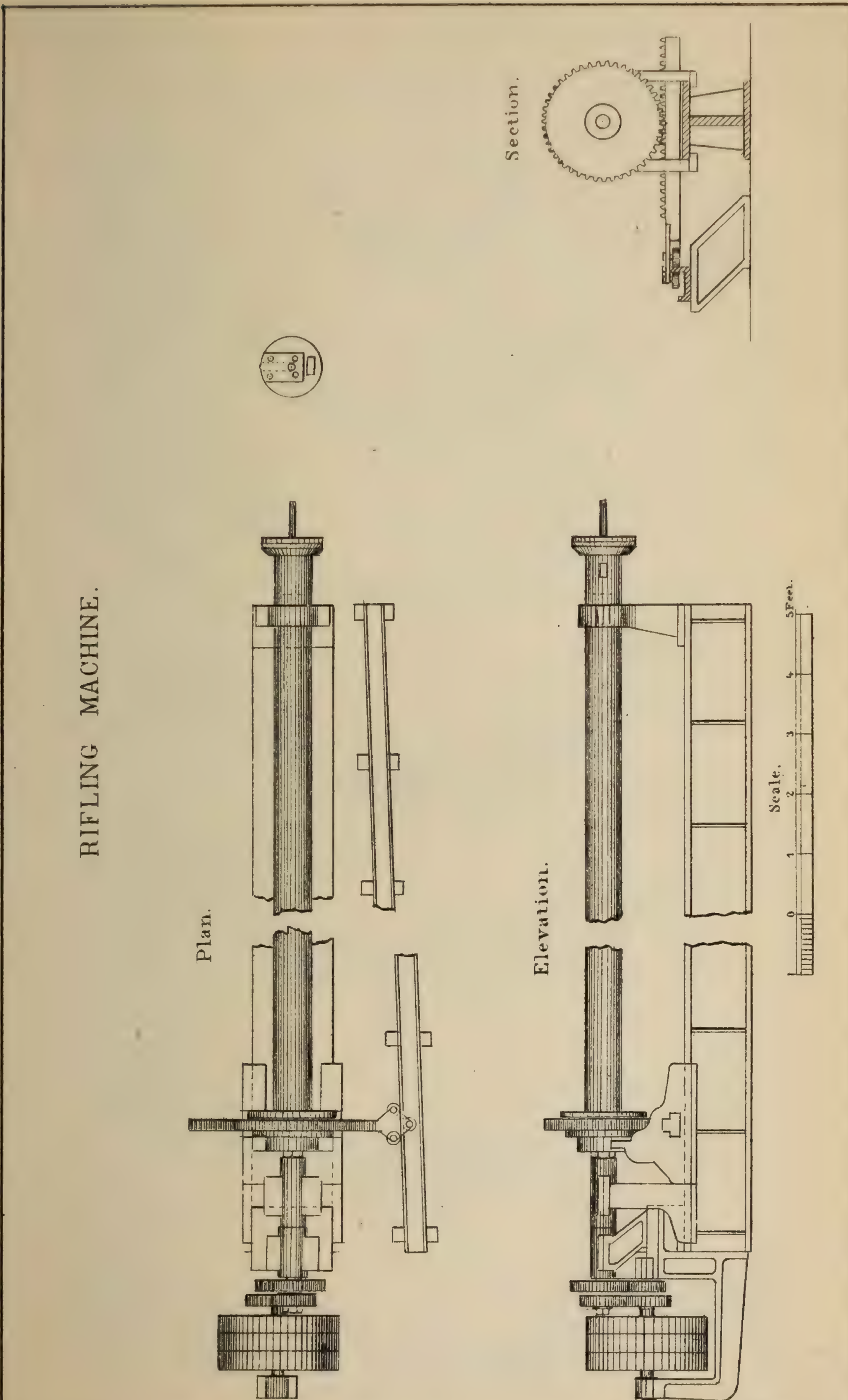


Appendix 9—1880.

RIFLING MACHINE.

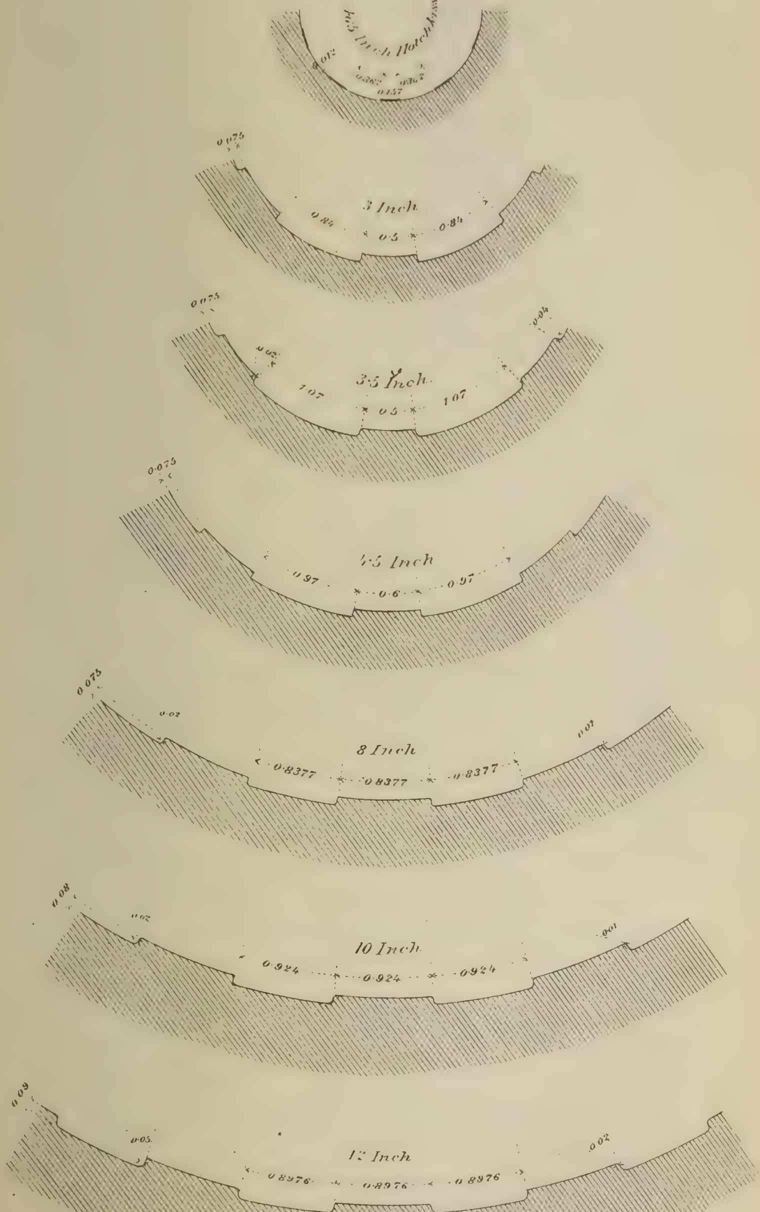


Appendix 9—1880.



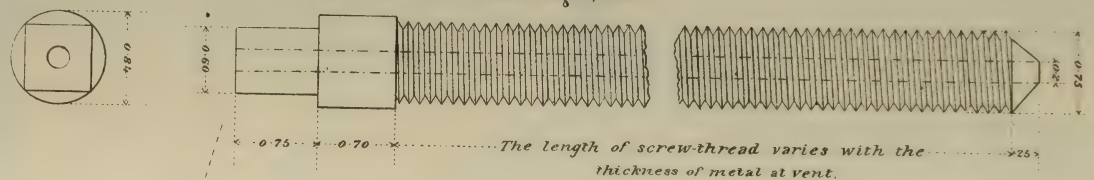
Appendix 9—1880.

DETAILS OF RIFLING. SERVICE GUNS.

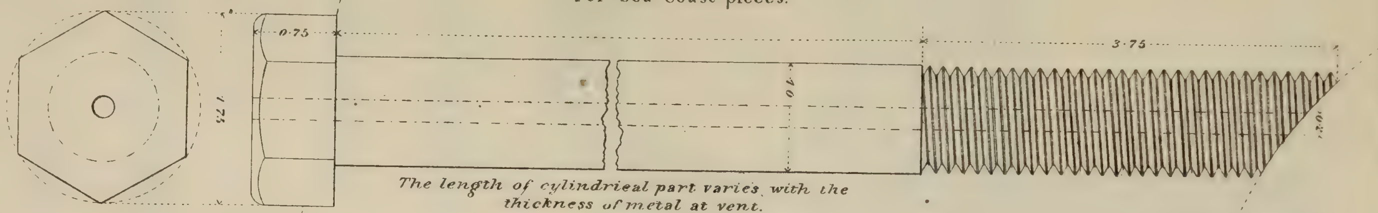


DETAILS OF VENTING. SERVICE GUNS.

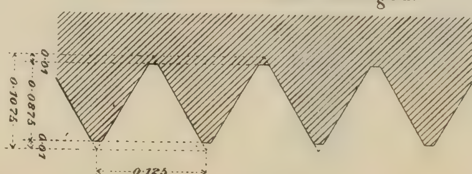
For Field and Siege pieces.



For Sea Coast pieces.



Section of thread enlarged.



Diameter calipers.

Fig. 1.

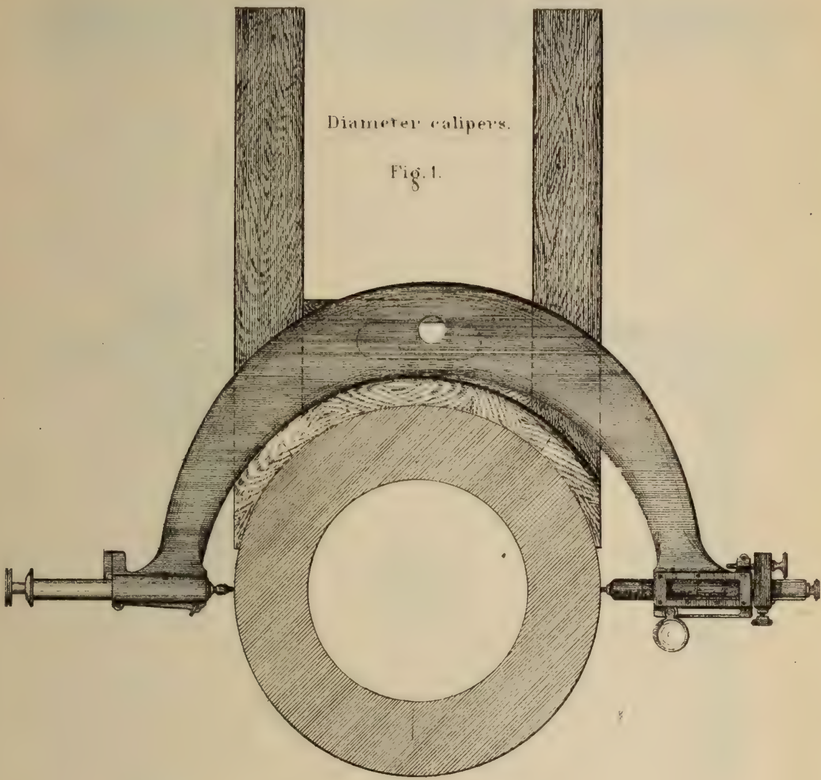
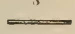


Fig. 2.

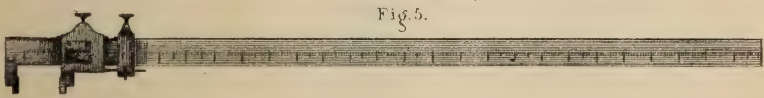
Fig. 3.

Fig. 4.

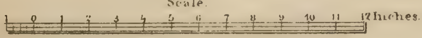


Standard scale.

Fig. 5.



Scale.



Appendix 9—1880.

Star gauge.

Fig. 1.

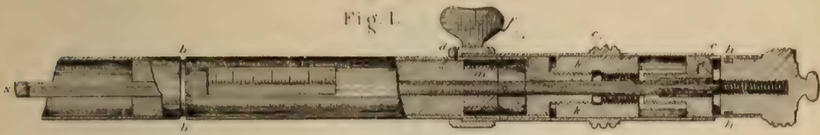
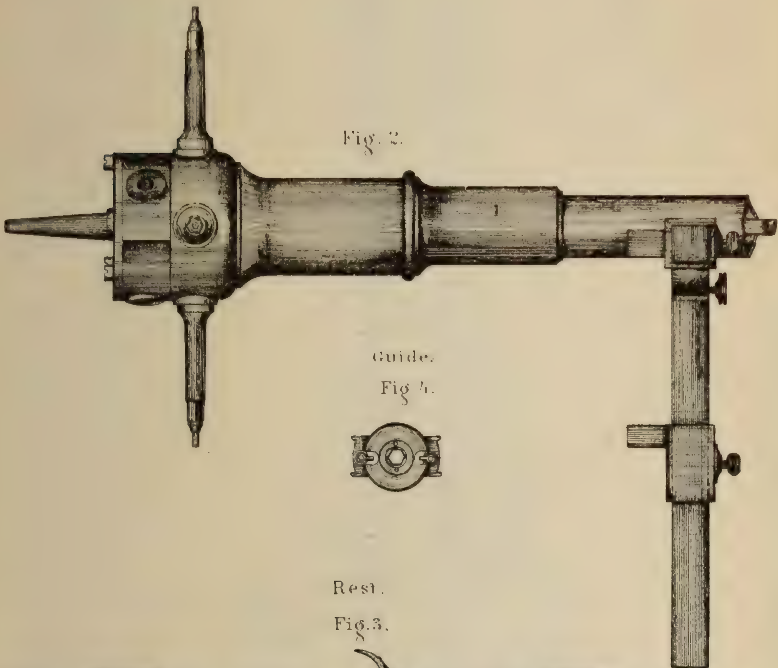


Fig. 2.

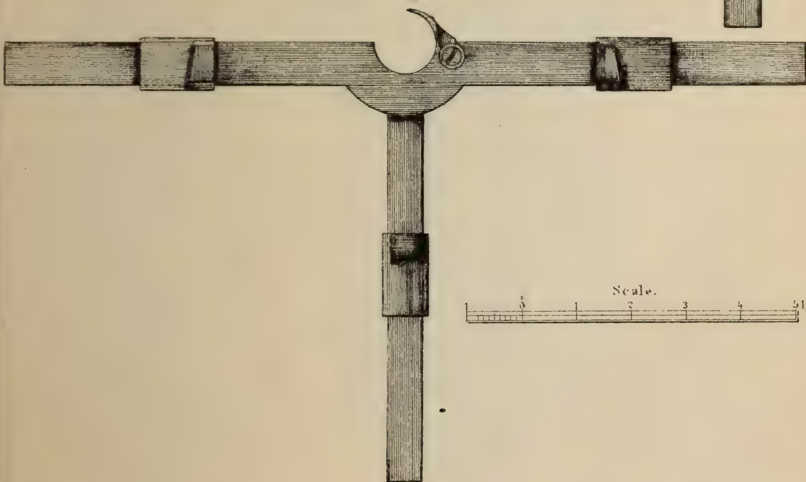


Guide.

Fig. 4.

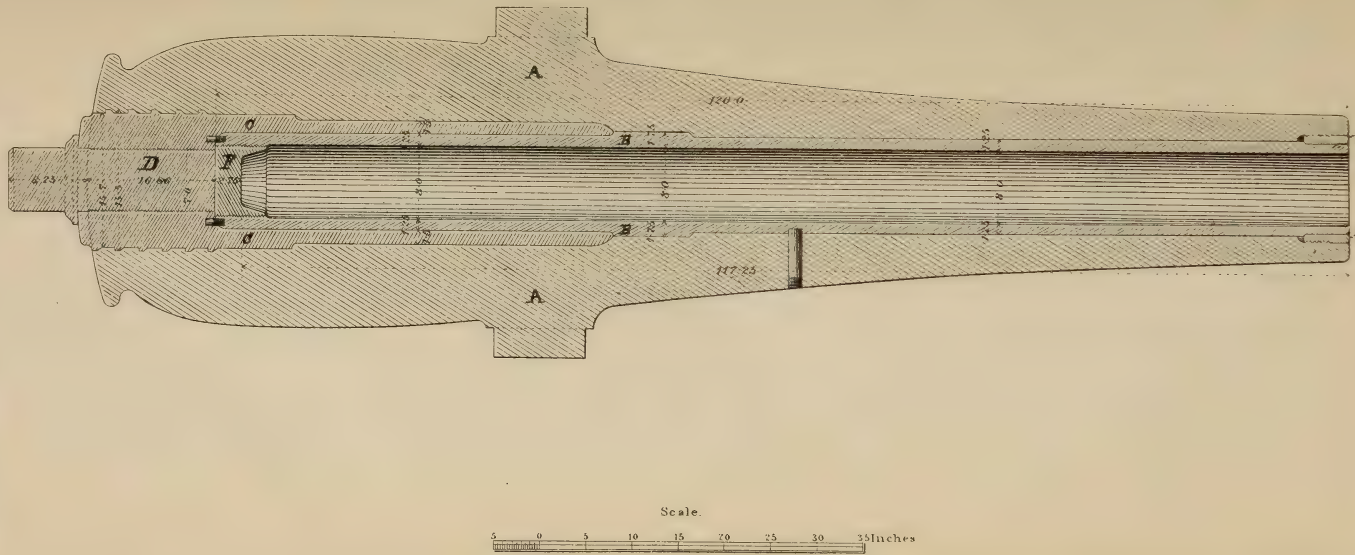
Rest.

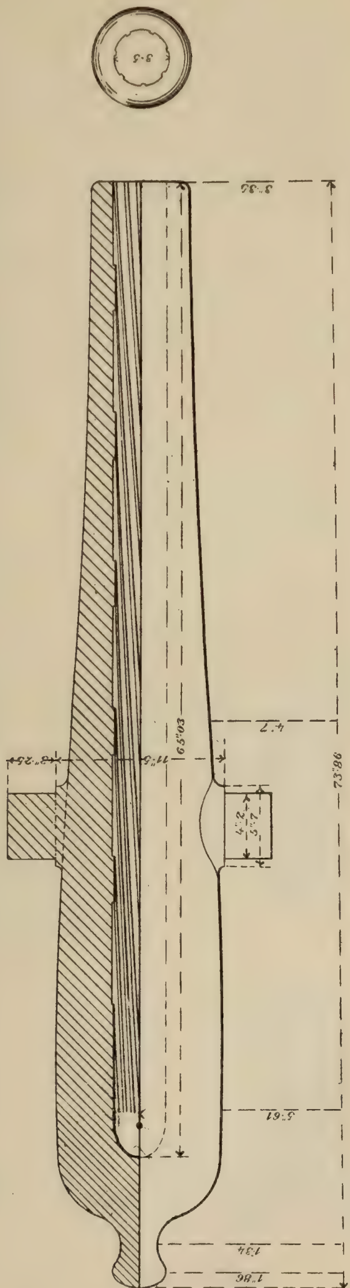
Fig. 3.



Scale.

8 INCH B.I. RIFLE. PRESENT SYSTEM OF CONVERSION.




3.5
3".85
65".03
73".86
4".7
11".5
3".25
4".2
3".7
5".61
1".34
1".86

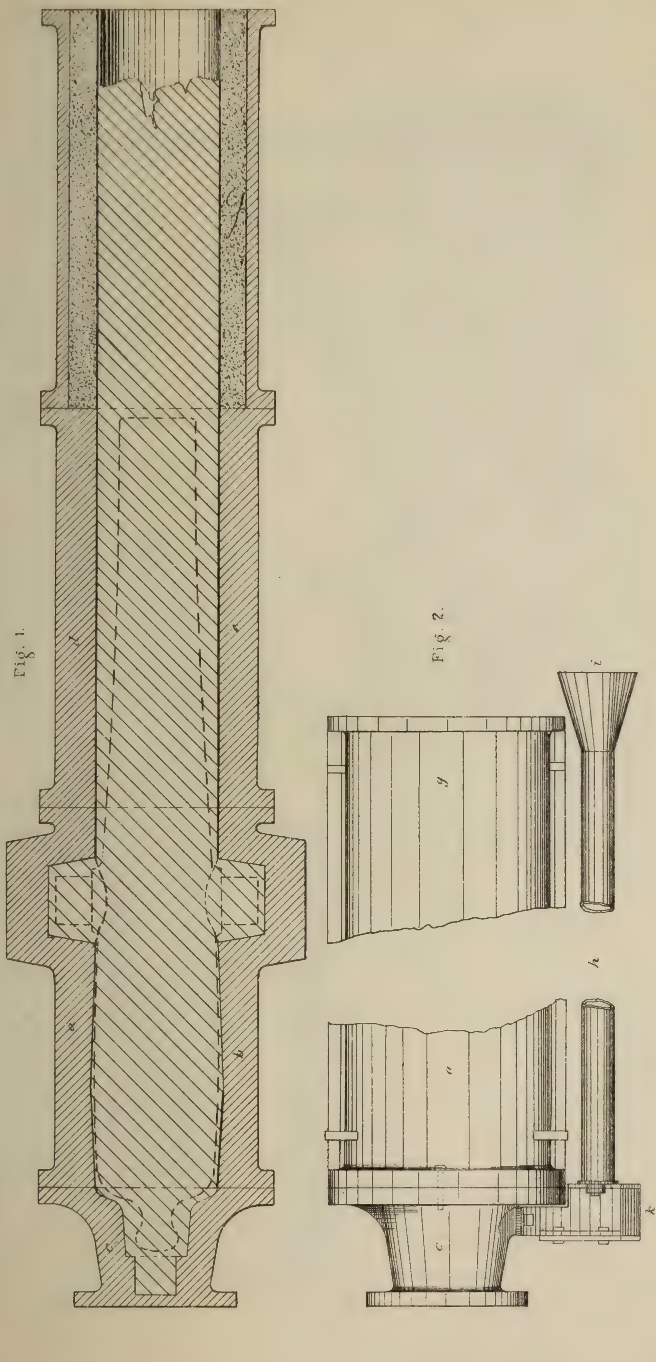
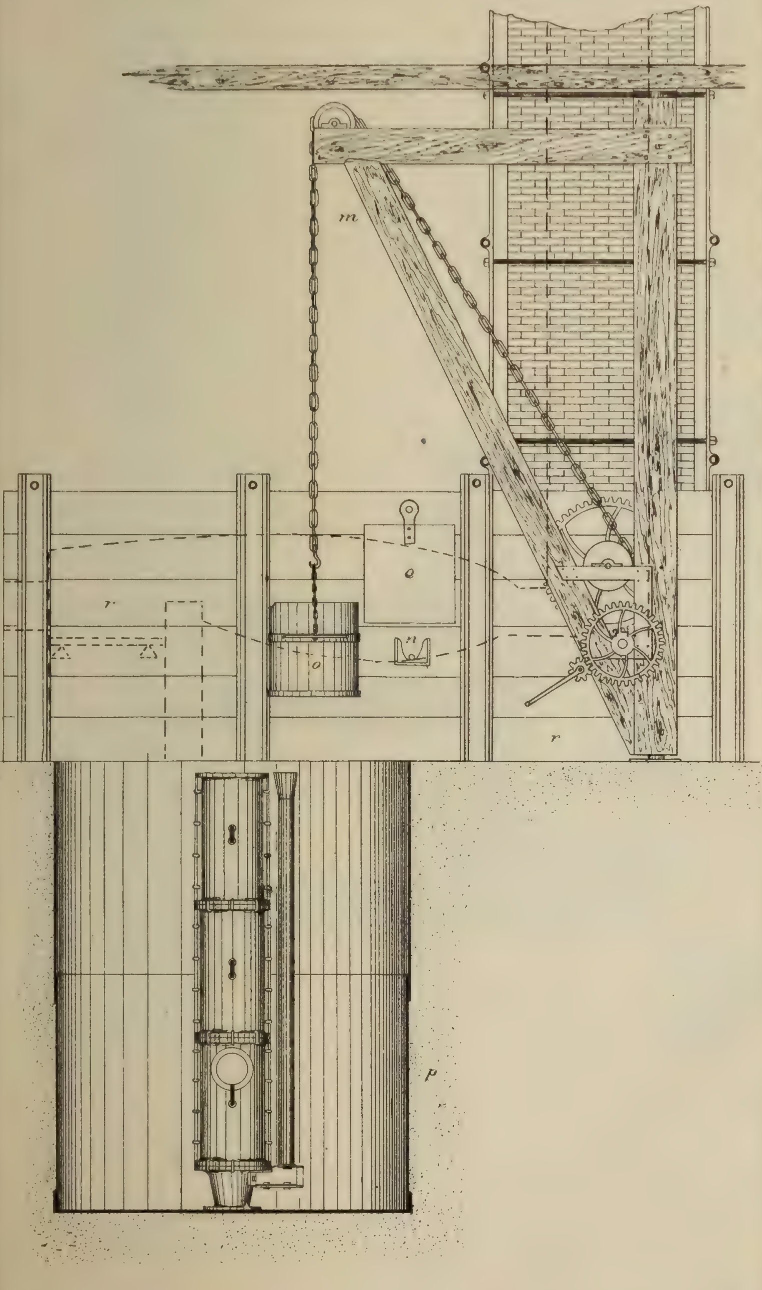
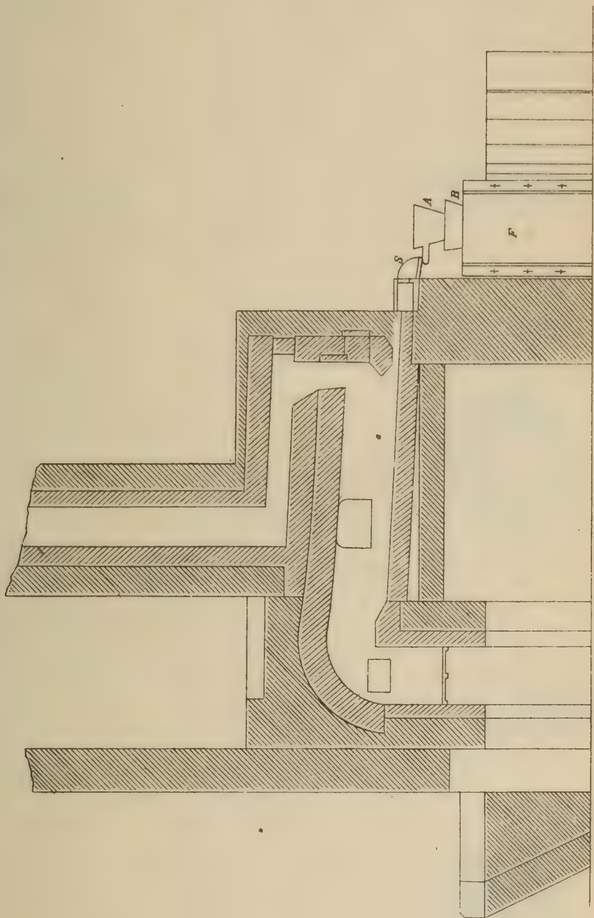


Fig. 1.

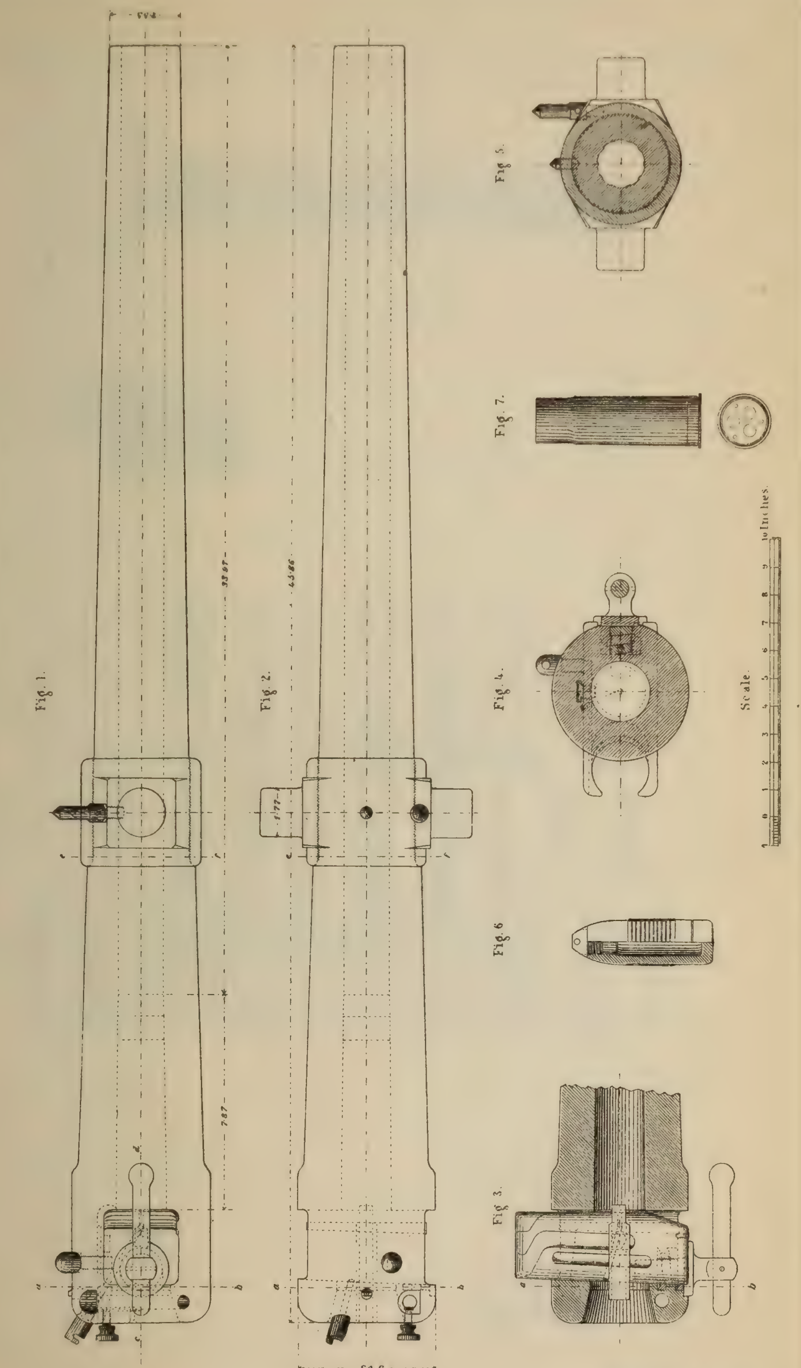
Fig. 2.



Appendix 9 —1880.


A
B
F
S

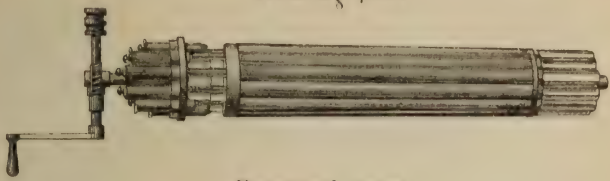
HOTCHKISS B. L. MOUNTAIN GUN CAL. 1·65



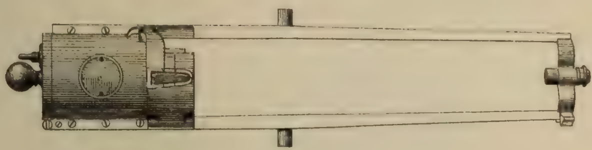
Appendix 9—1880.

DETAILS OF GATLING GUN, WITH DEVELOPMENT OF FIRING MECHANISM.

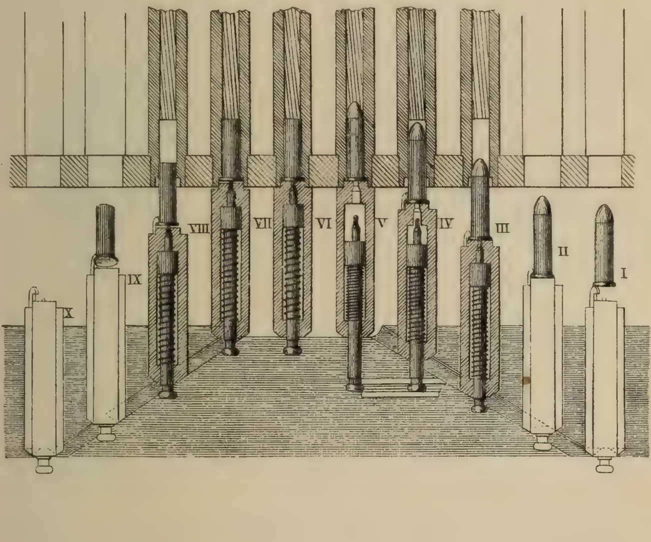
Revolving parts.



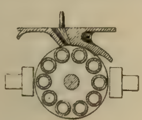
Frame and casing.



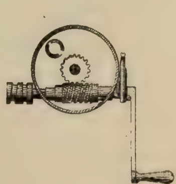
Developement of cam.



Section through hopper.

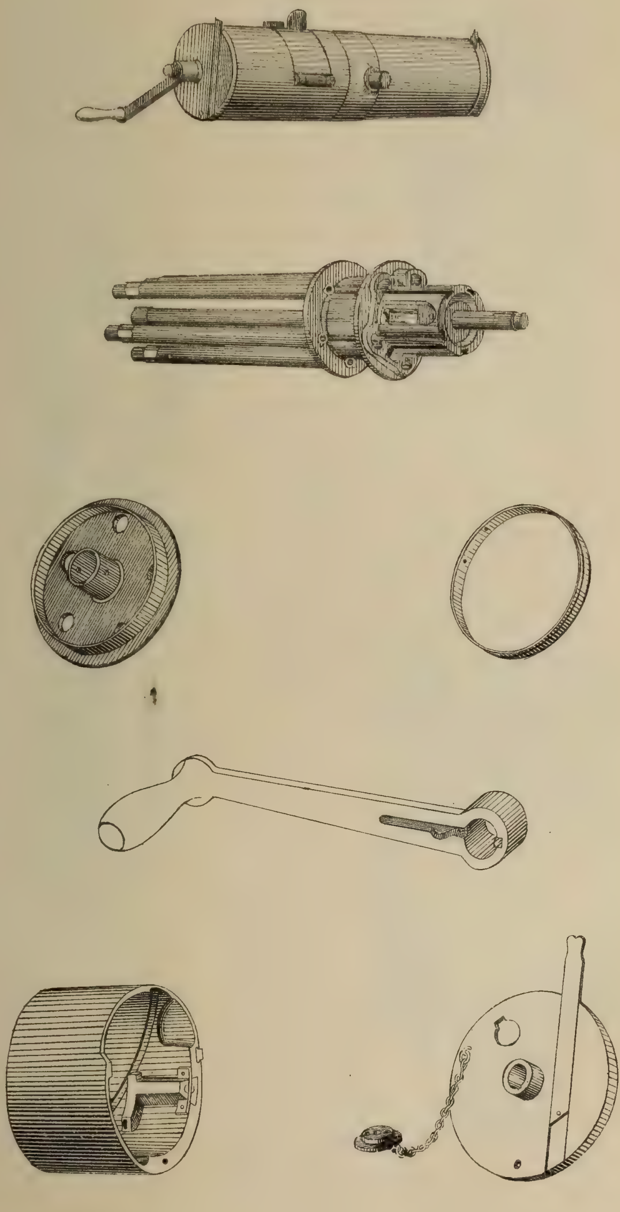


Revolving gear.

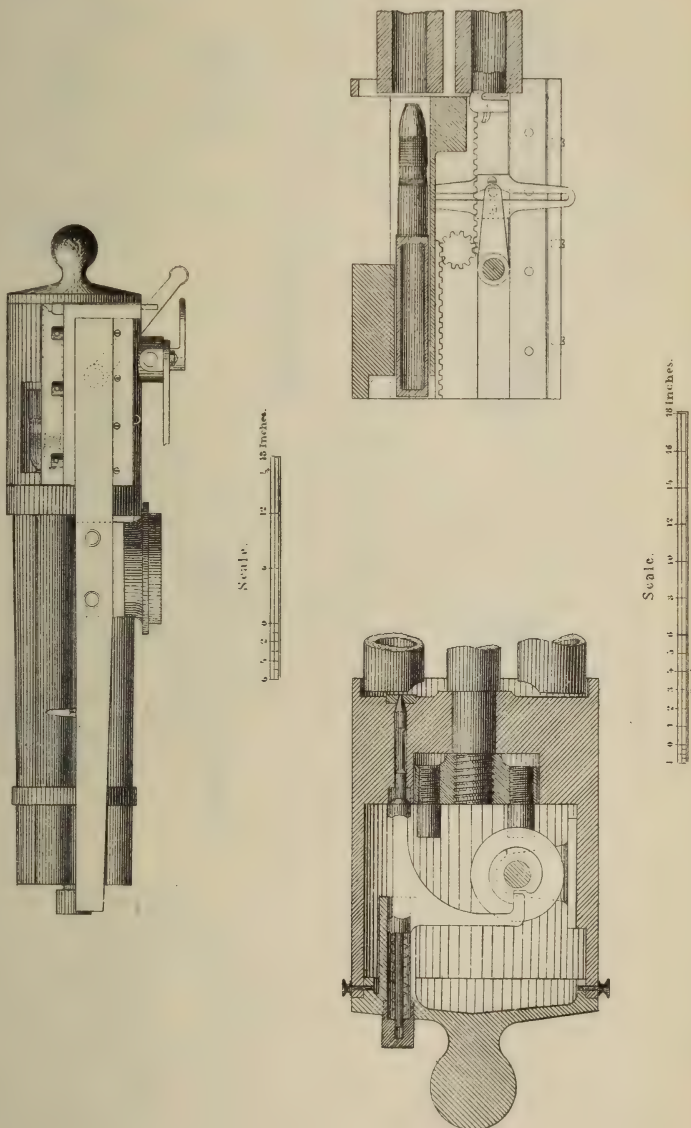


Appendix 9—1880.

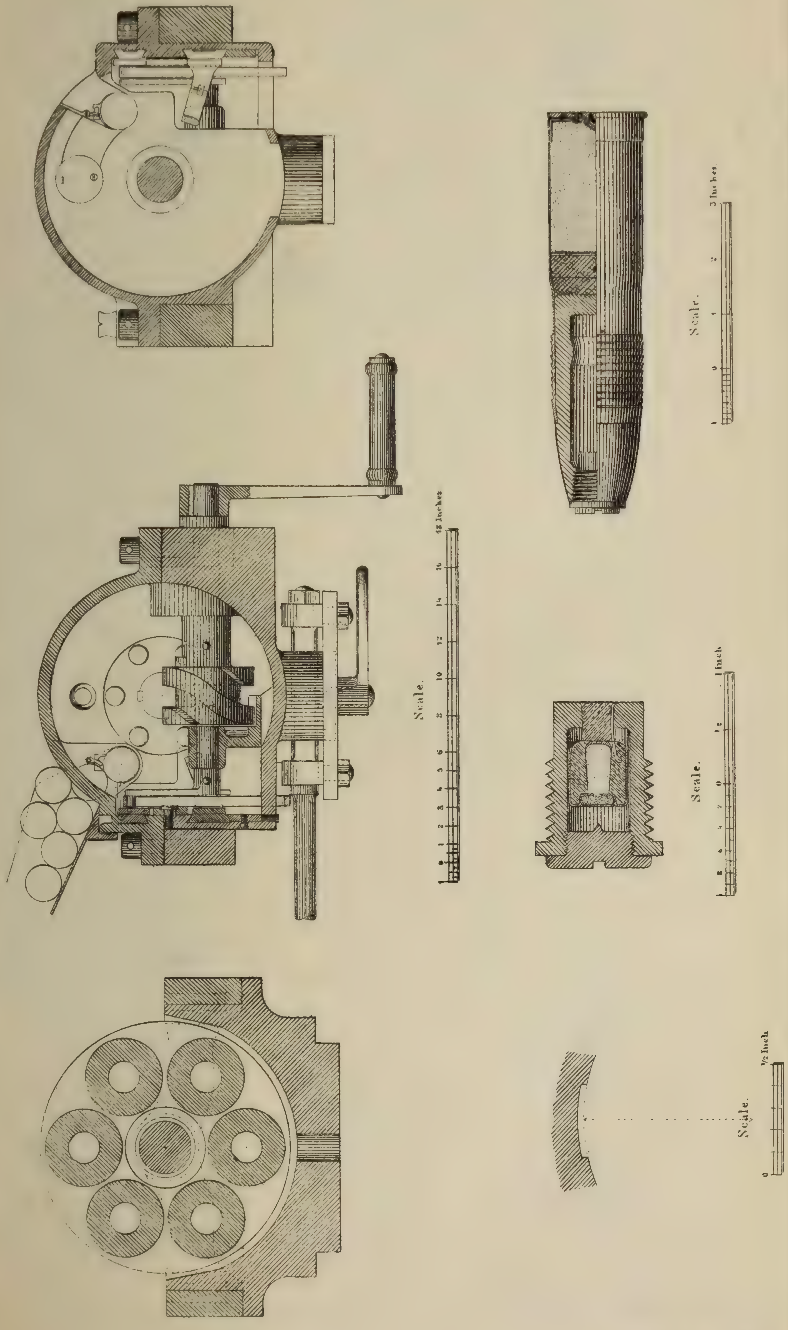
DETAILS OF CAVALRY GATLING GUN CAL. 45



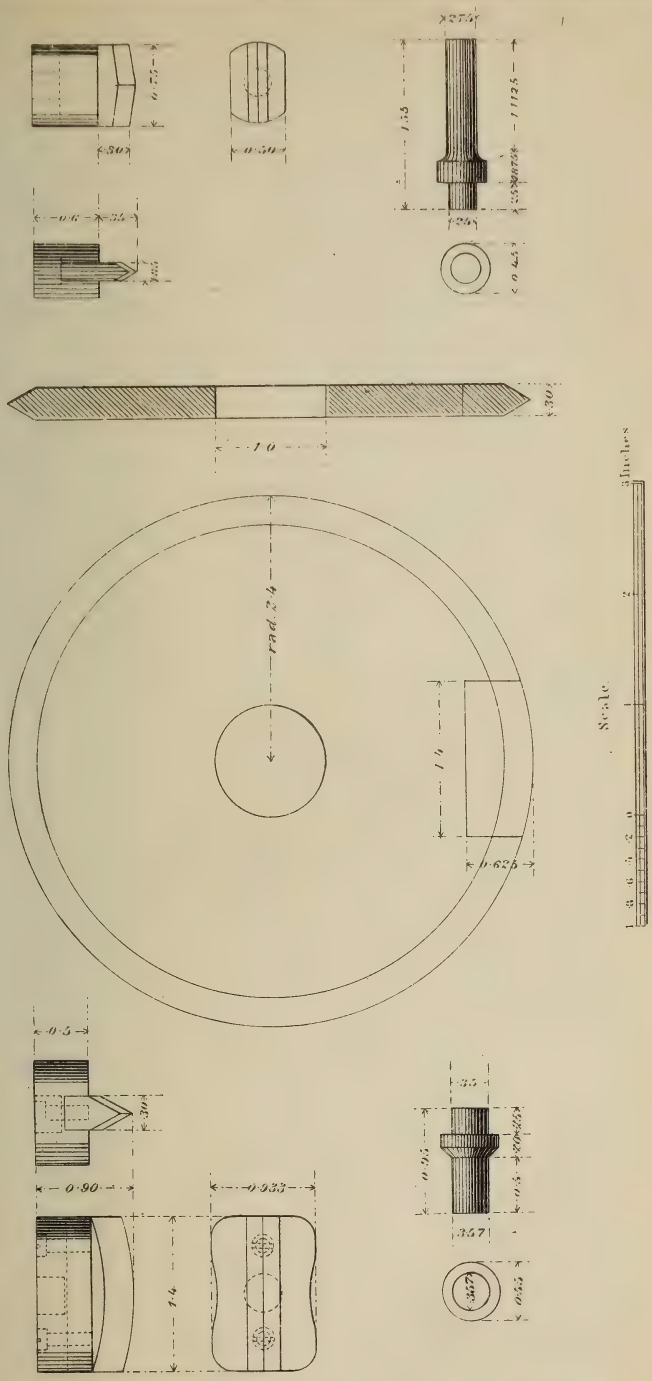
HOTCHKISS CANNON REVOLVER CAL. 1·45



HOTCHKISS CANNON REVOLVER CAL. 1·45

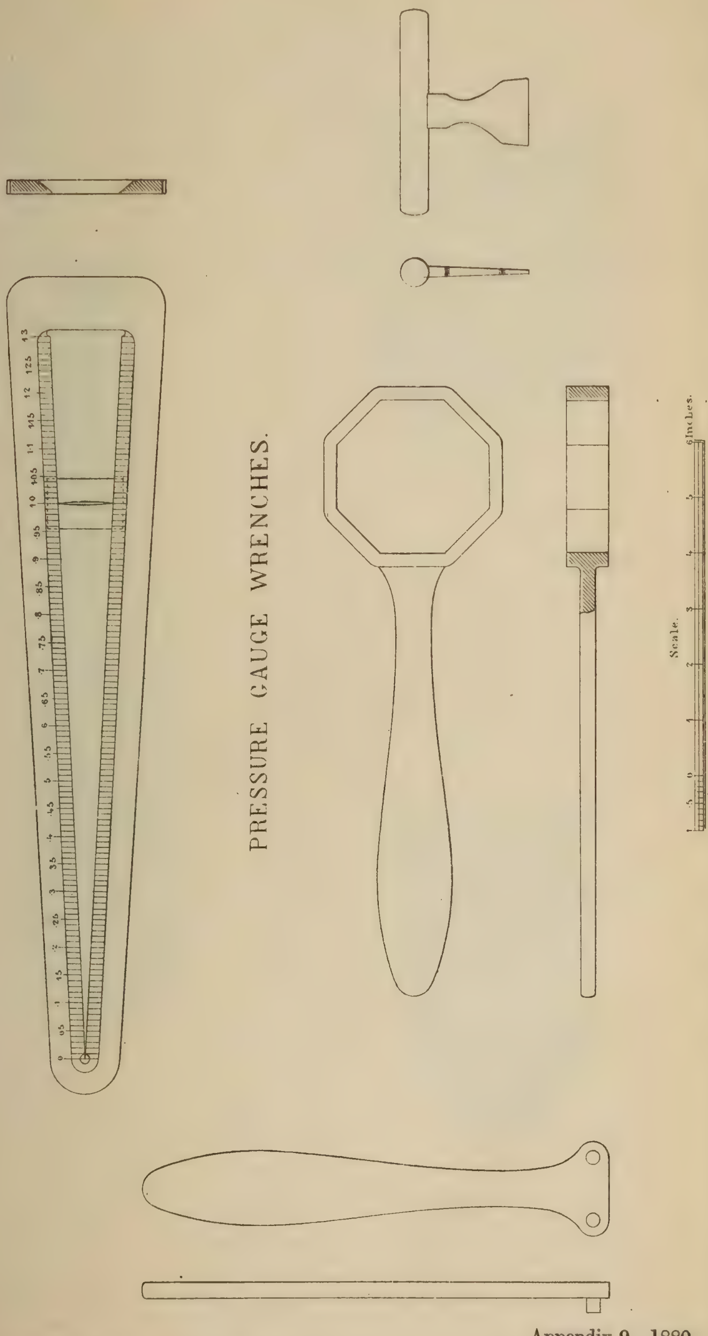


DETAILS OF KNIVES AND PISTONS FOR PRESSURE GAUGES.

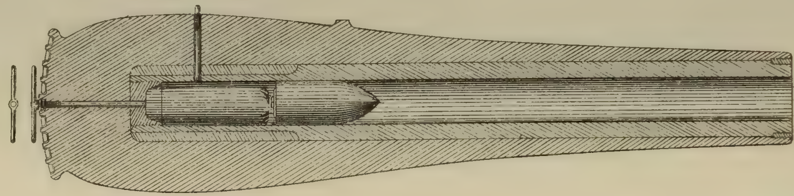


GAUGE FOR MEASURING THE LENGTH OF INDENTATIONS.

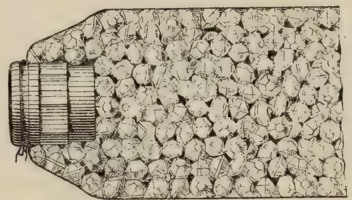
PRESSURE GAUGE WRENCHES.



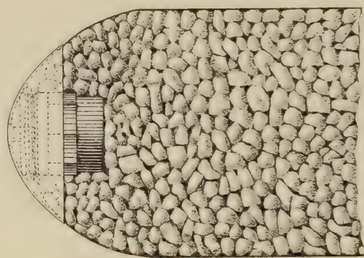
MODE OF EMPLOYING PRESSURE GAUGES.



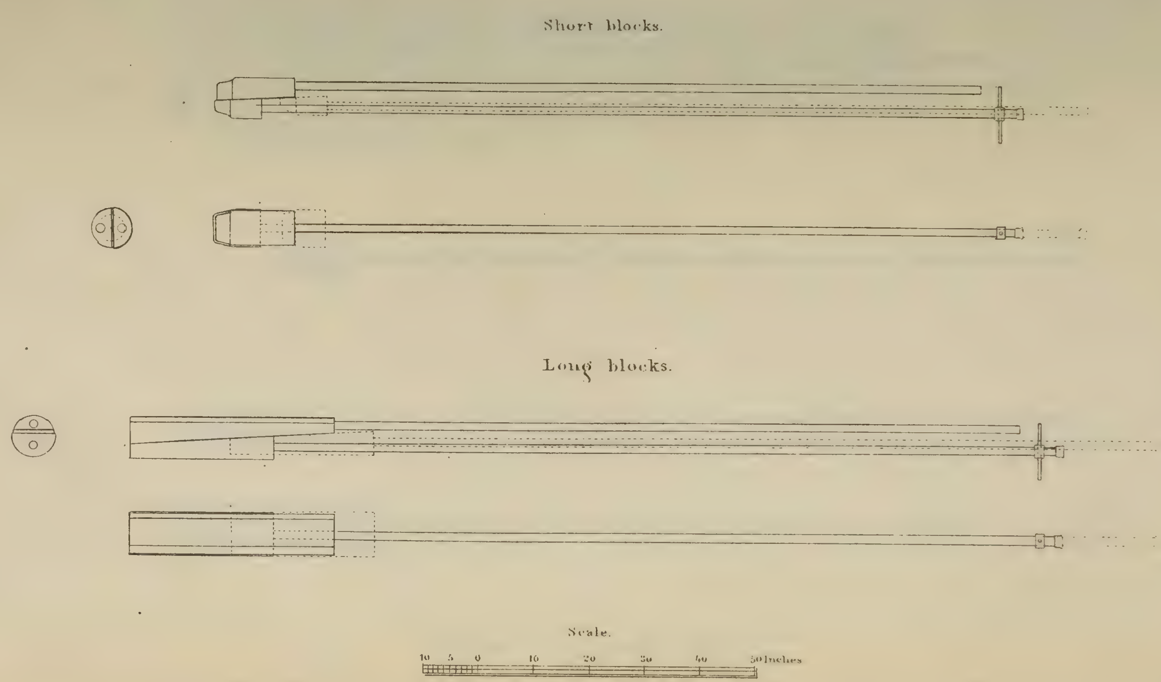
8 in. Rifle Cartridge.



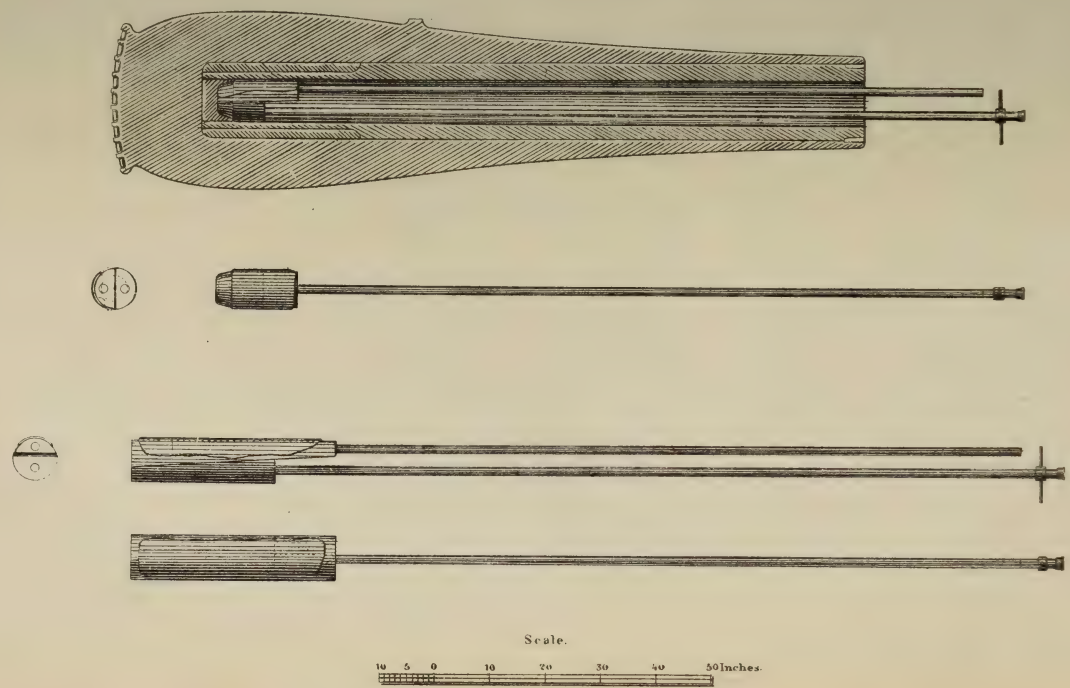
10 in. S.B. Cartridge.



BLOCKS FOR TAKING GUTTA-PERCHA IMPRESSIONS OF THE BORES OF GUNS.



METHOD OF TAKING GUTTA-PERCHA IMPRESSIONS OF THE BORES OF GUNS.



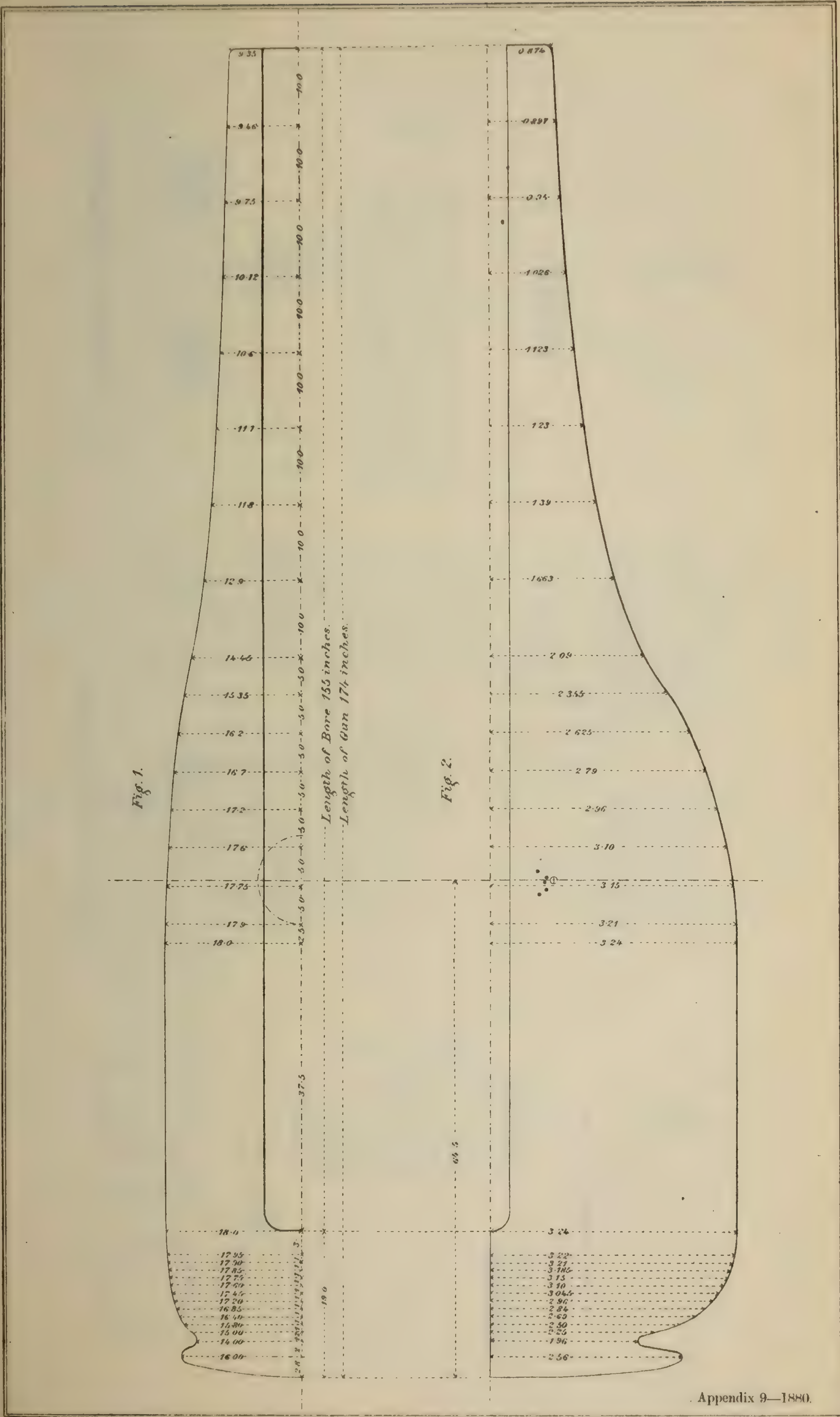
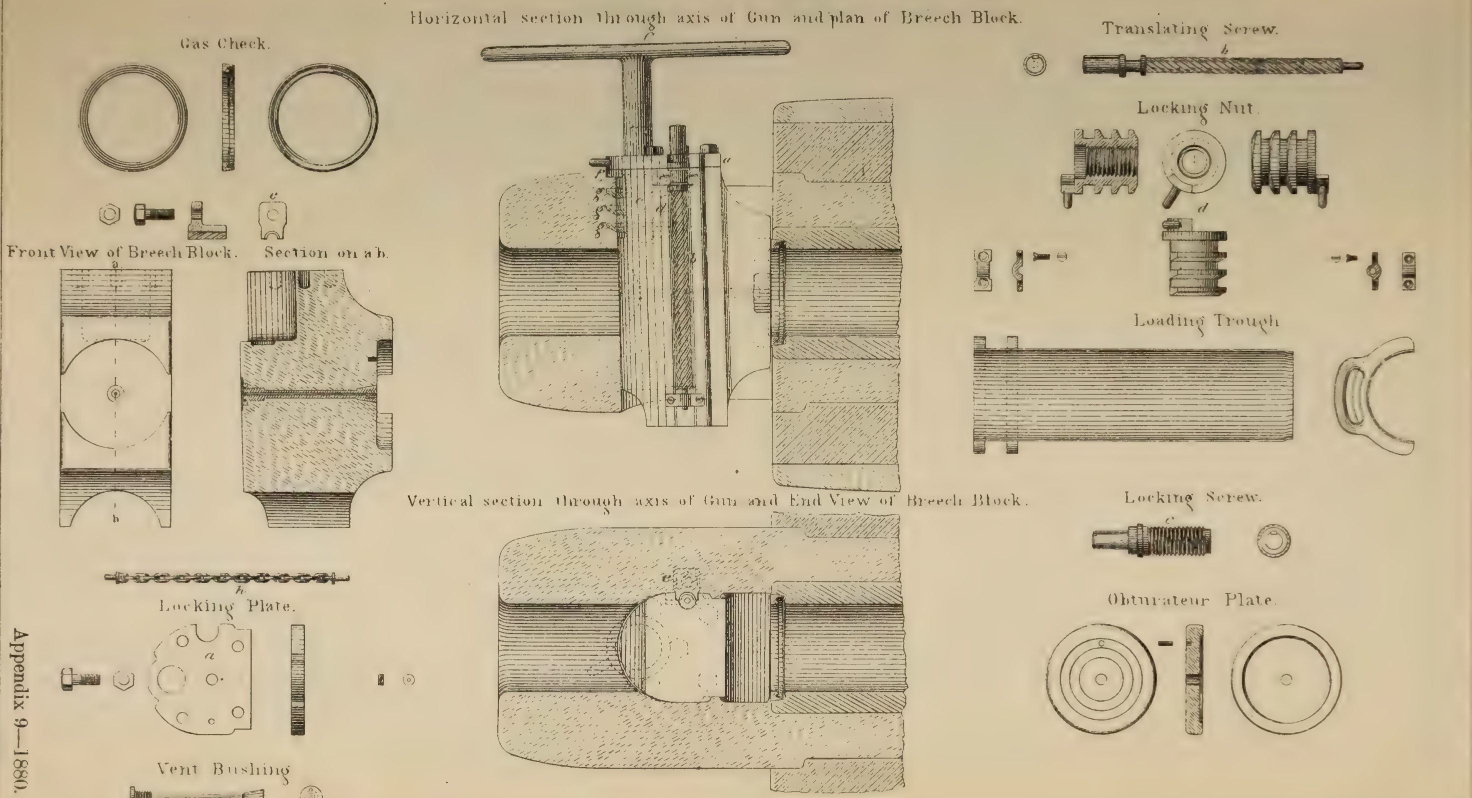


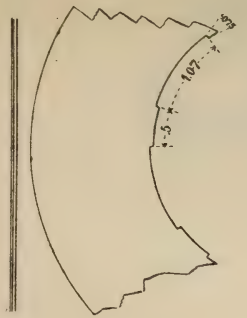
Fig. 1.
Fig. 2.
Length of Bore 155 inches.
Length of Gun 174 inches.

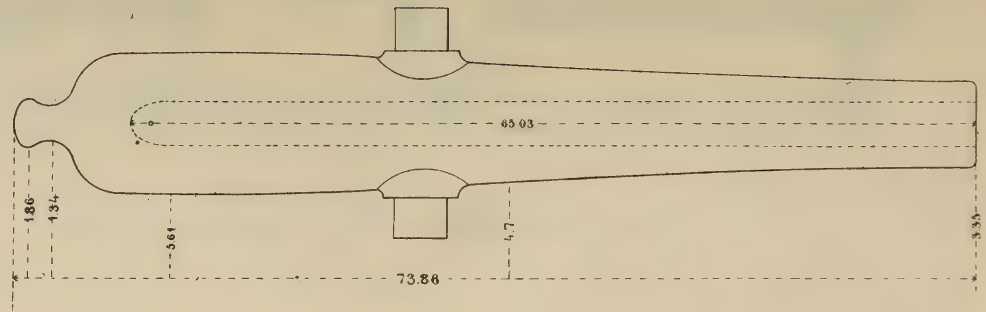
PARTS OF 8 INCH B.L. RIFLE.



Appendix 9—1880.

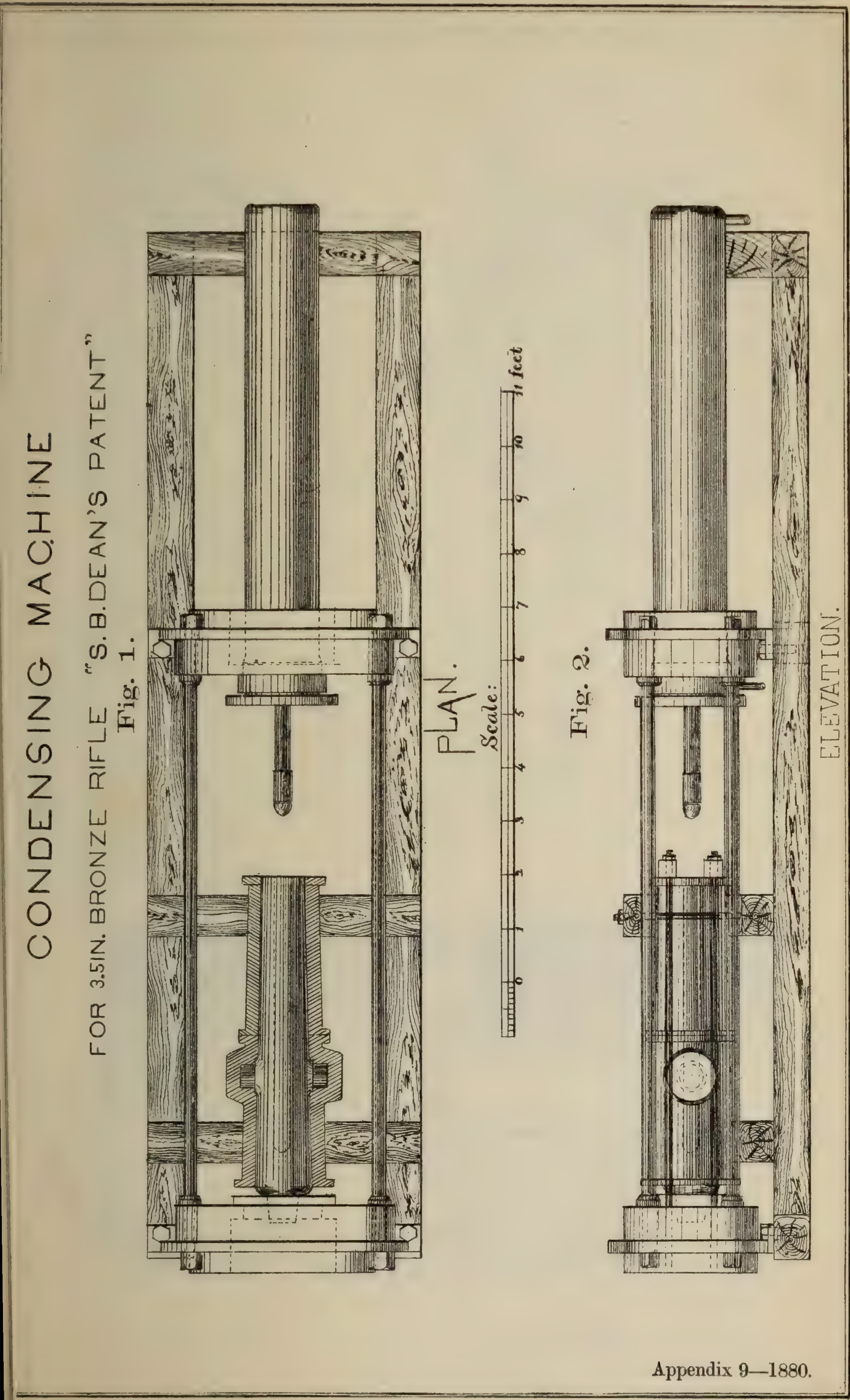
$3\frac{1}{2}$ in. M. L. BRONZE GUN (DEAN'S PATENT)

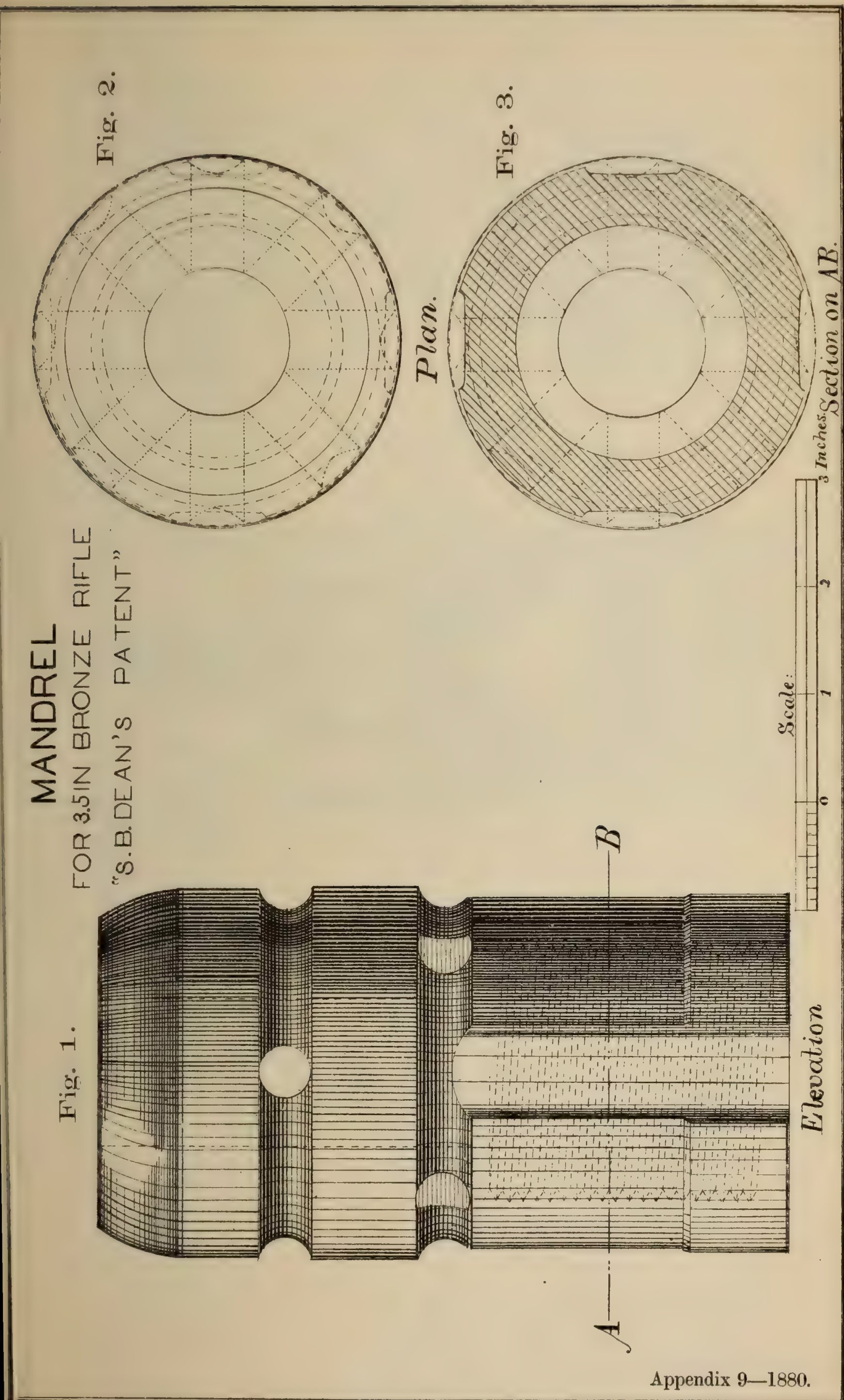


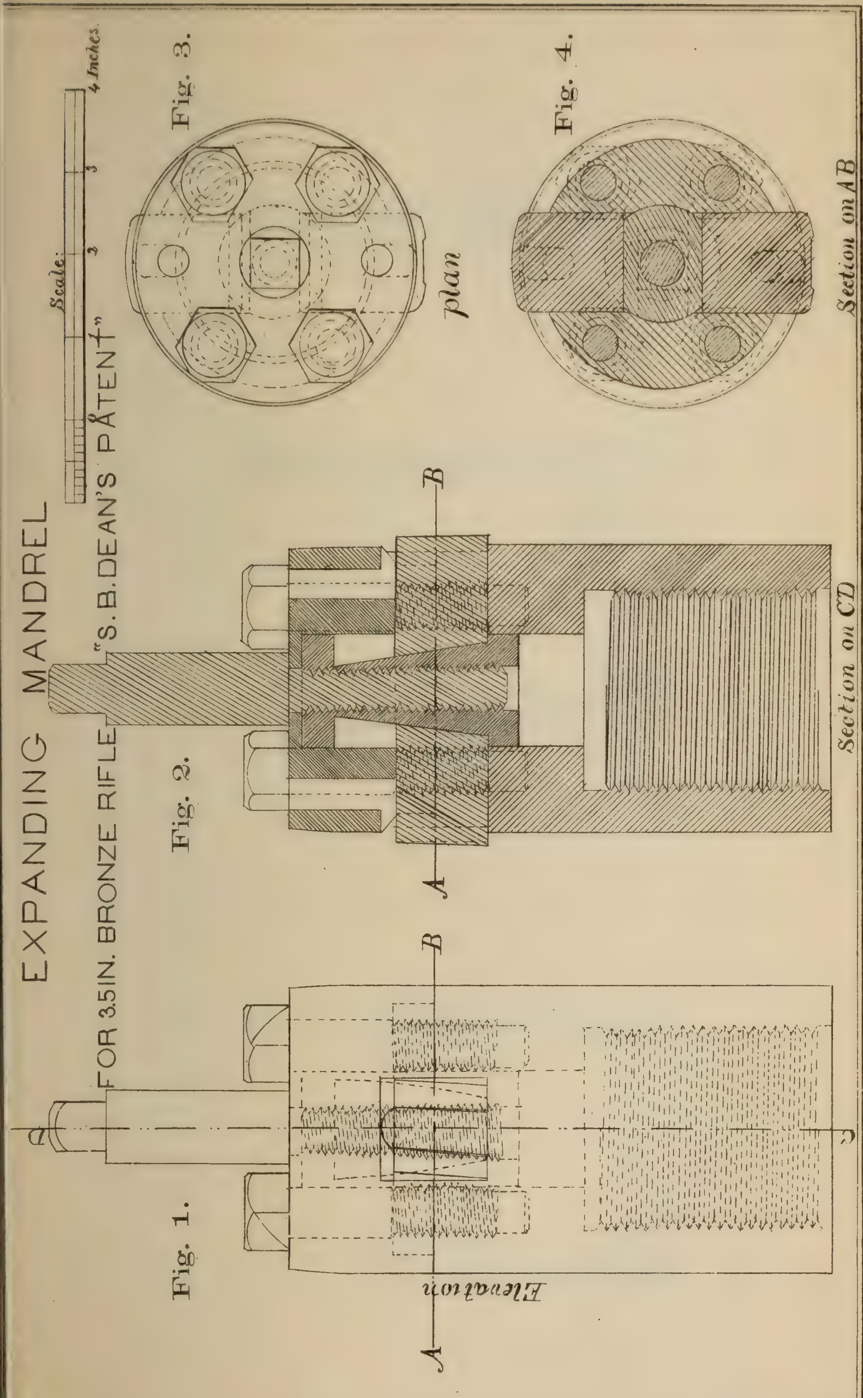


No preponderance.
Twist uniform, one turn in 12 feet.
7 Grooves and lands.
Weight 1322 lbs

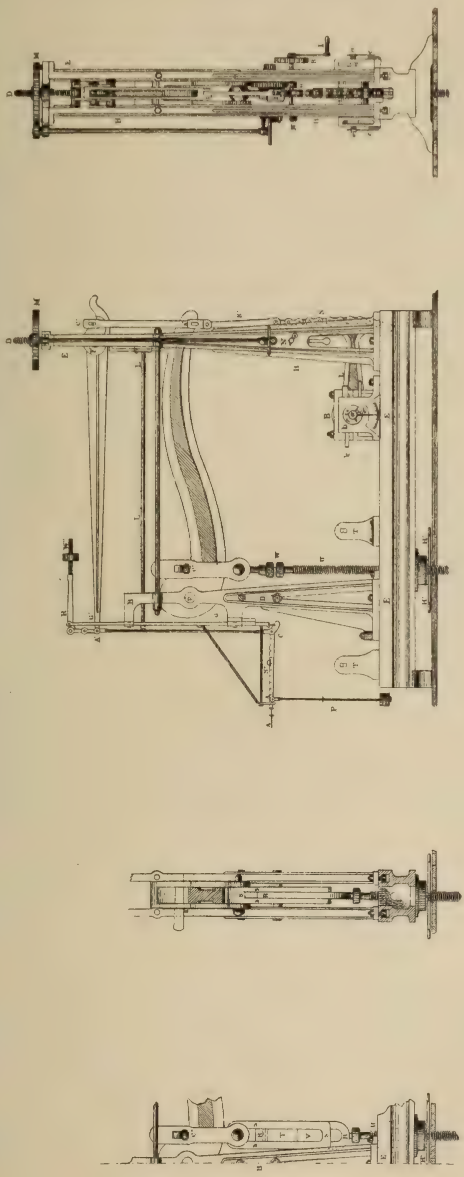
Scale.
10 9 8 7 6 5 4 3 2 1 0 10 20 30 Inches.


CONDENSING MACHINE
FOR 3.5IN. BRONZE RIFLE "S.B.DEAN'S PATENT"
Fig. 1.
PLAN.
Scale:
0 1 2 3 4 5 6 7 8 9 10 11 feet
Fig. 2.
ELEVATION.

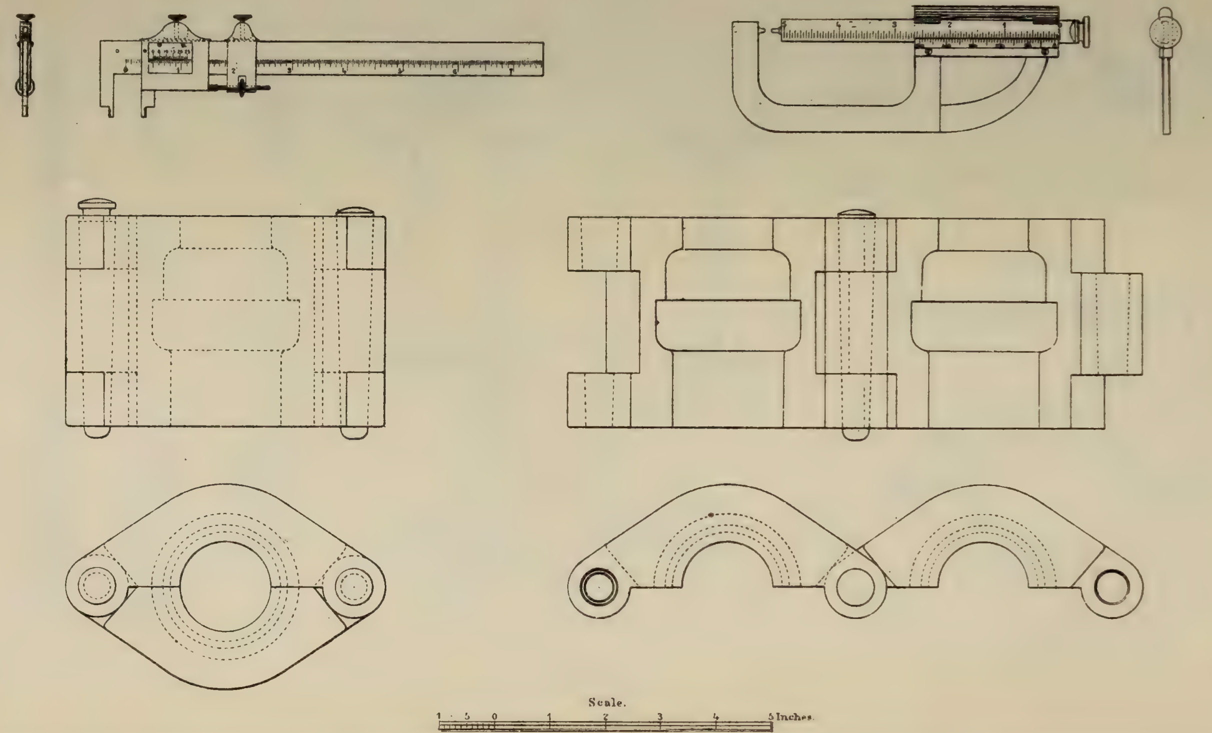

MANDREL
FOR 3.5IN BRONZE RIFLE
"S.B.DEAN'S PATENT"
Fig. 1.
Fig. 2.
Fig. 3.
Plan.
Elevation
Section on AB.
A
B
Scale:
0
1
2
3 Inches


EXPANDING MANDREL
FOR 3.5IN. BRONZE RIFLE "S. B. DEAN'S PATENT"
Scale:
1
2
3
4 Inches.
Fig. 1.
Elevation
Fig. 2.
Section on CD
Fig. 3.
plan
Fig. 4.
Section on AB
A
B

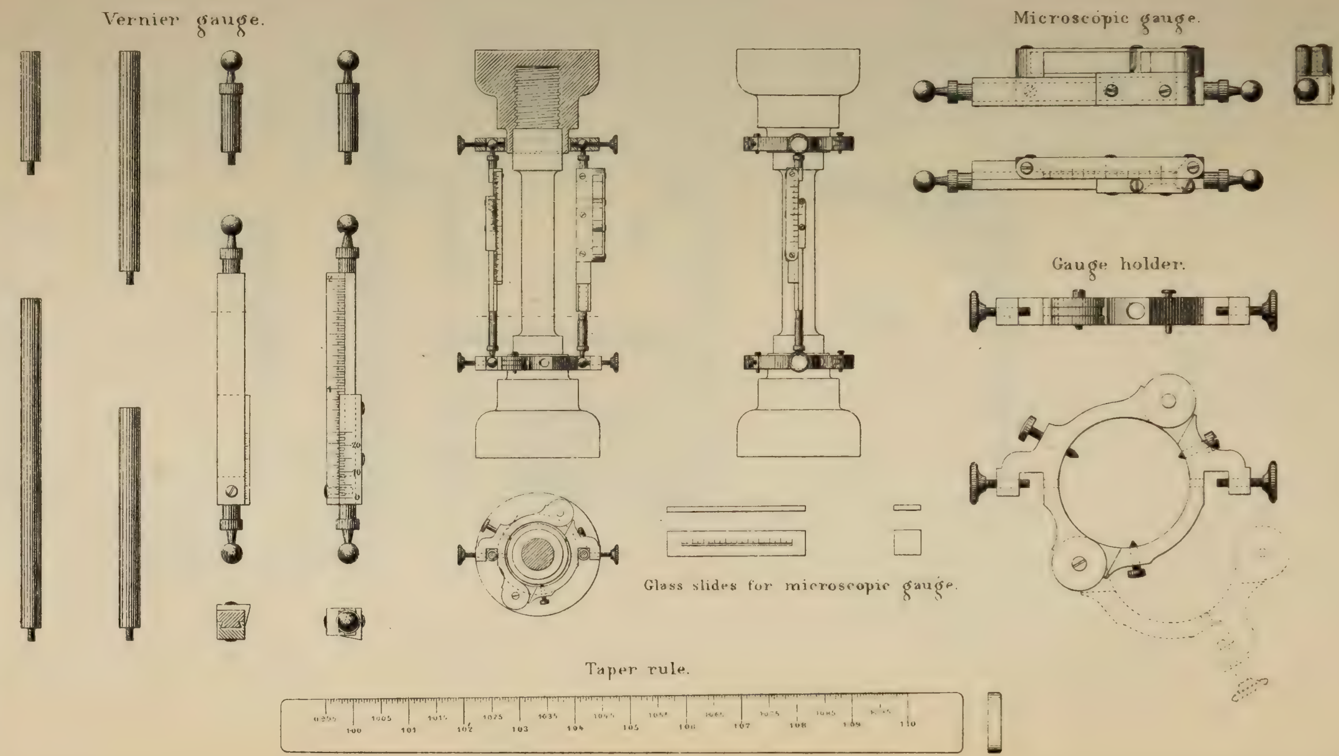
RODMAN TESTING MACHINE.



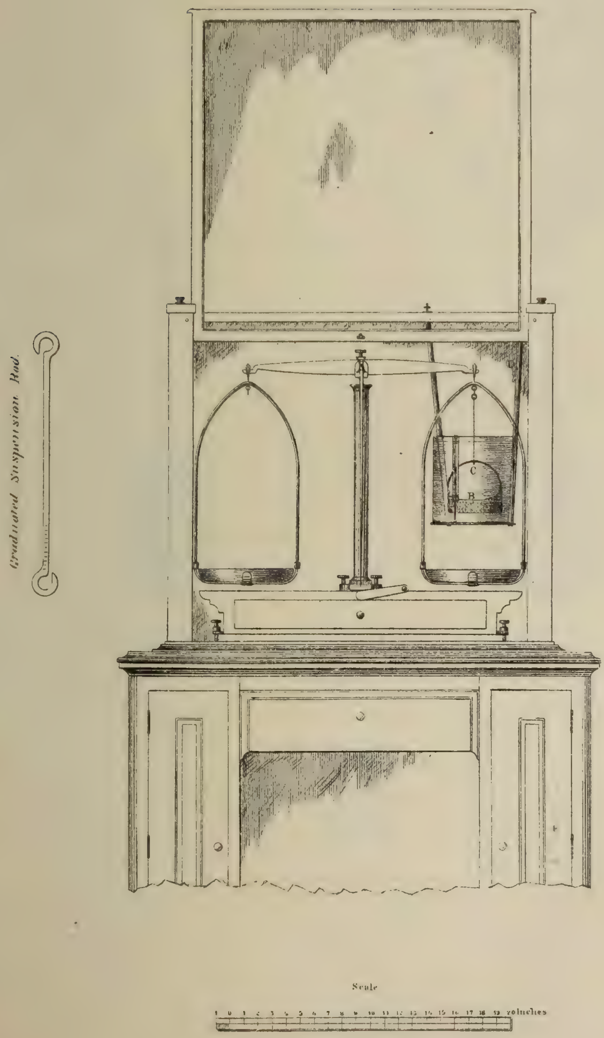
SPECIMEN CALIPERS AND CLAMPS.



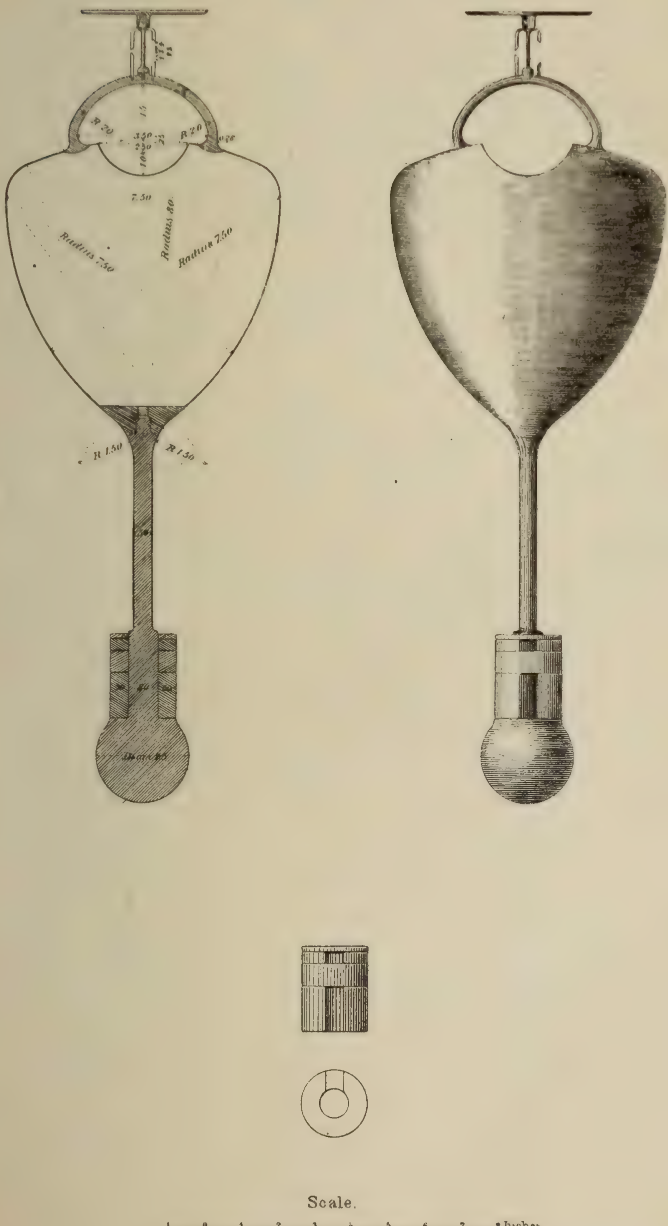
MEASURING INSTRUMENTS USED WITH TESTING MACHINE



METAL DENSIMETER.

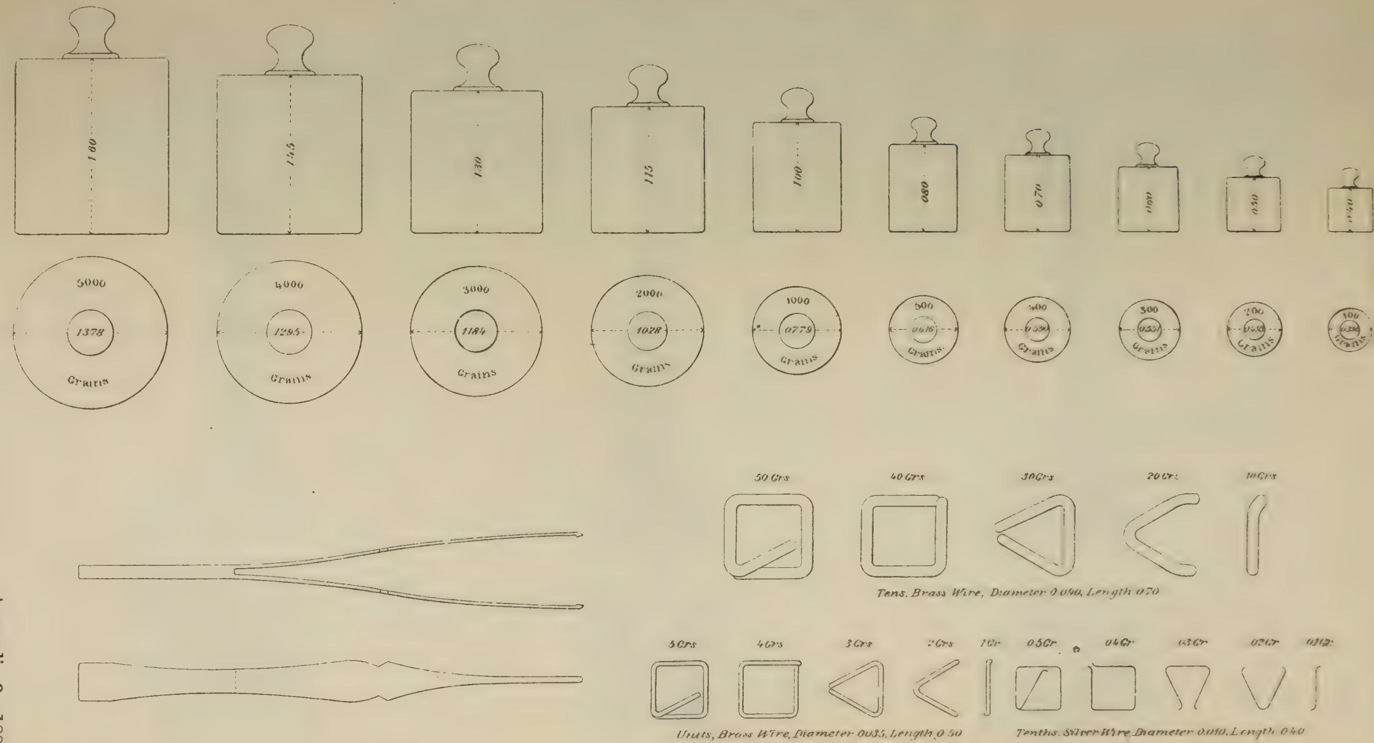


HYDROMETER.



Appendix 9—1880.

HYDROMETER WEIGHTS.

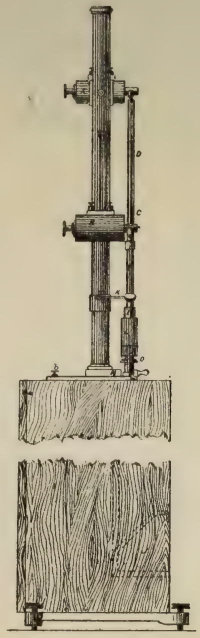


Appendix 9—1880.

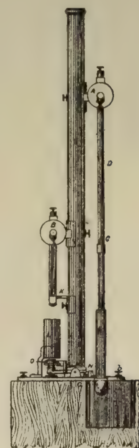
PLATE LIV.

THE LE BOULENGÉ CHRONOGRAPH.

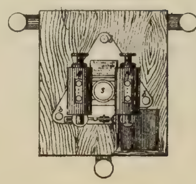
IN POSITION AS A VELOCIMETER.



Side View from the left.

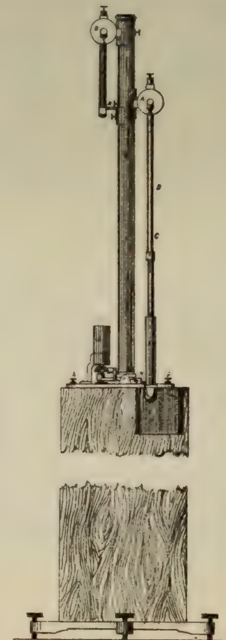


Front View.



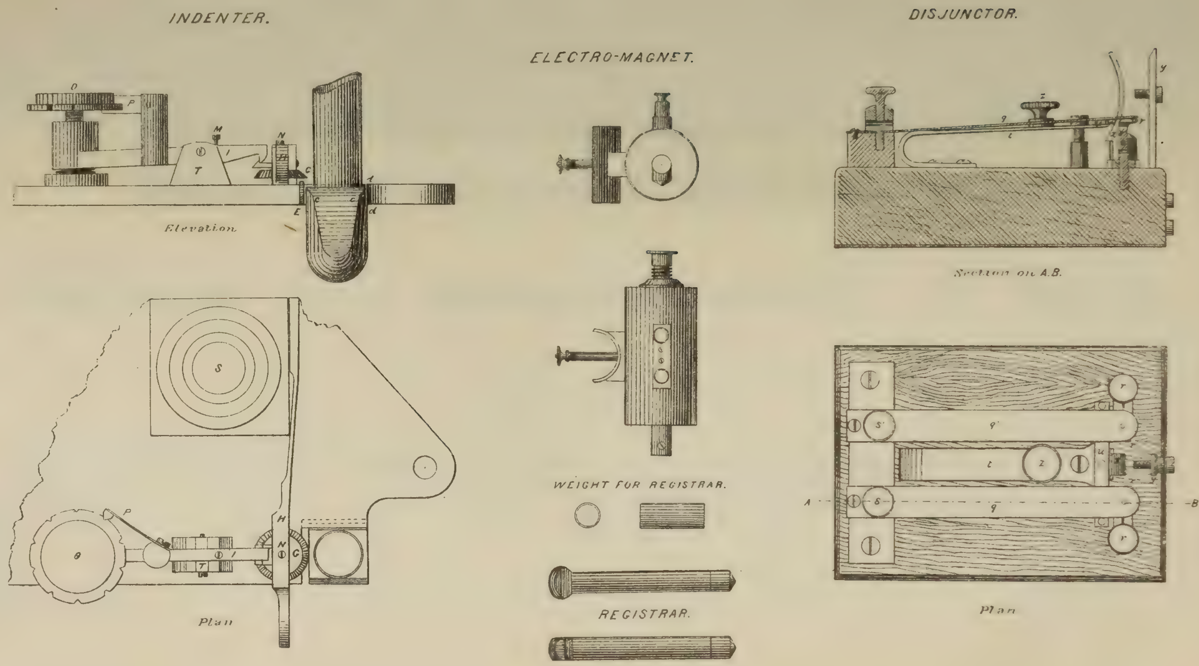
Top View.

IN POSITION AS A MICRO-CHRONOMETER.

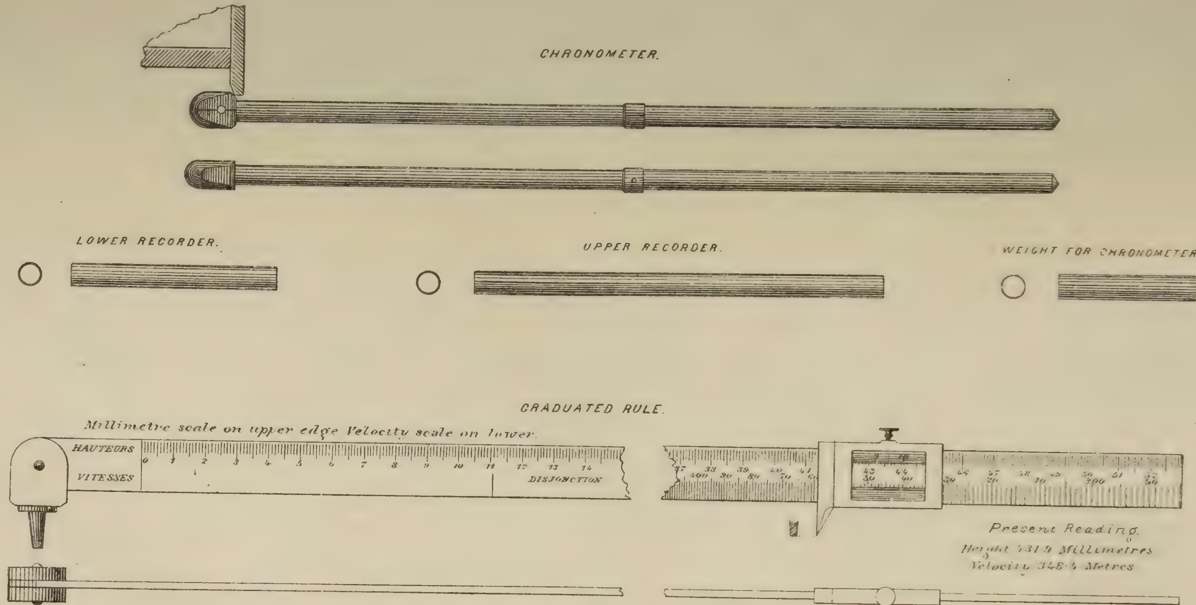


Front View.

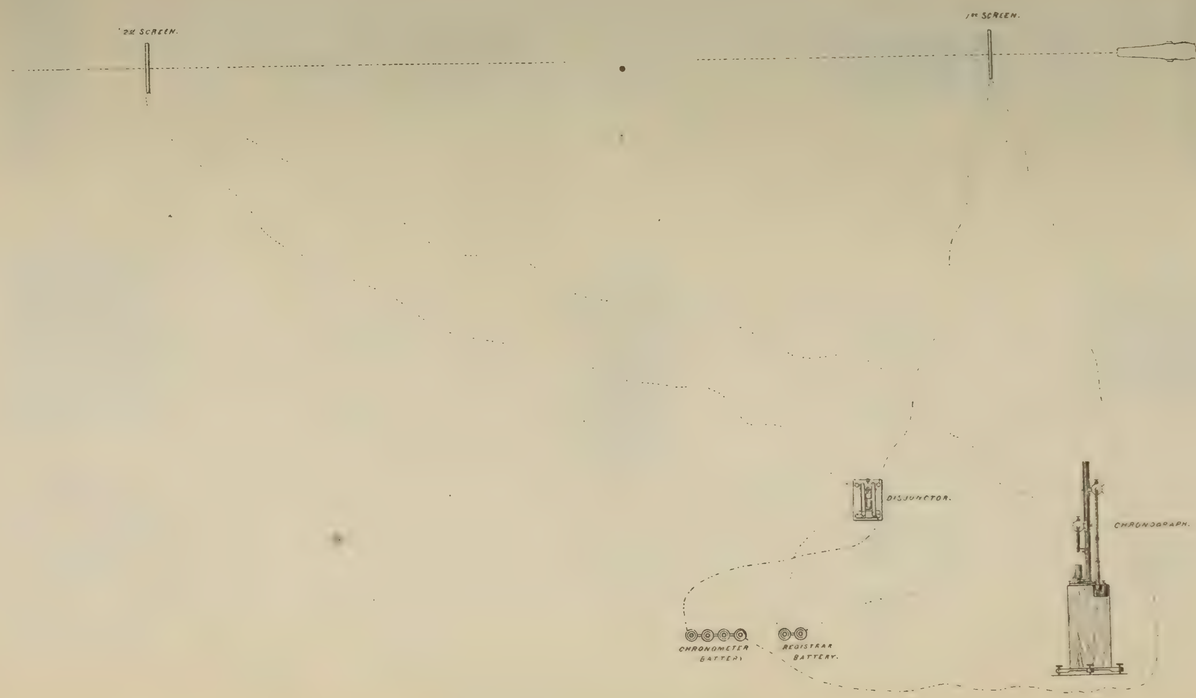
DETAILS OF CHRONOGRAPH.



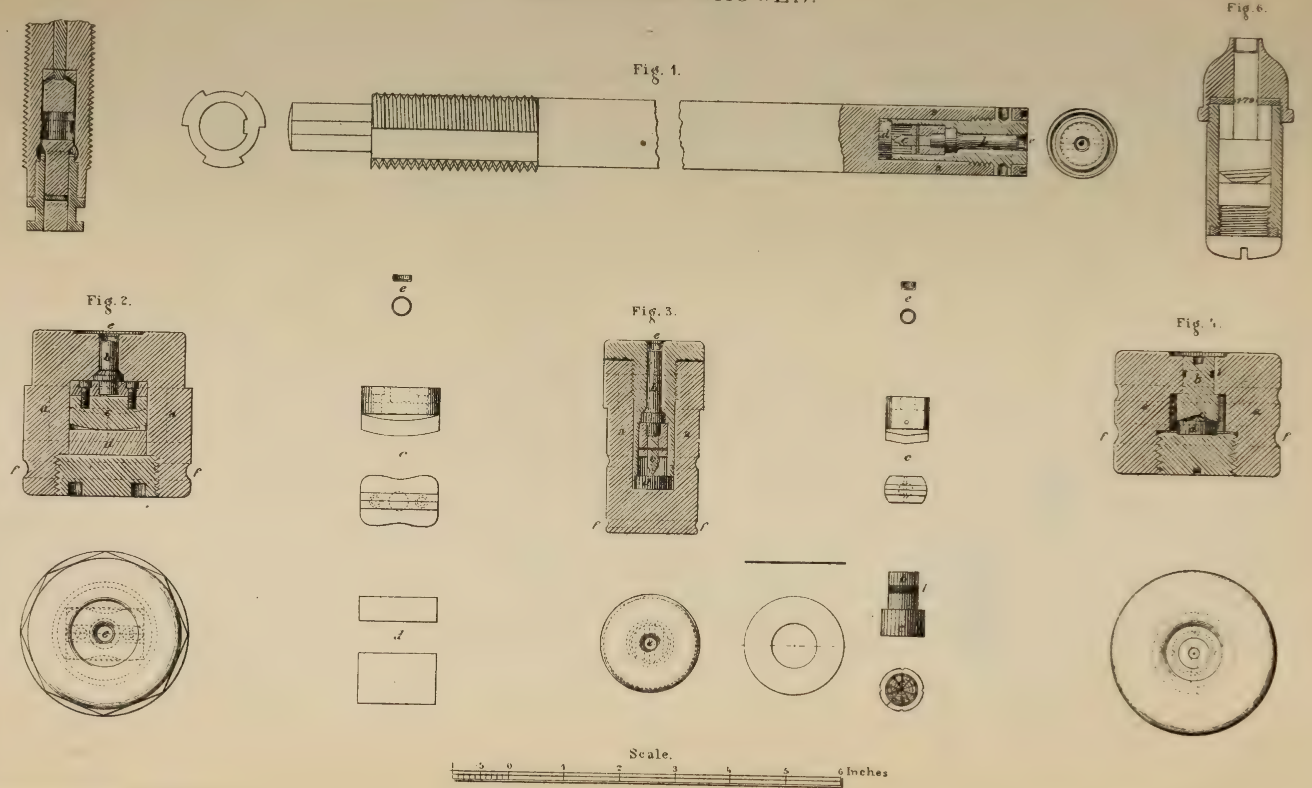
DETAILS OF CHRONOGRAPH.



EMPLOYMENT OF CHRONOGRAPH.



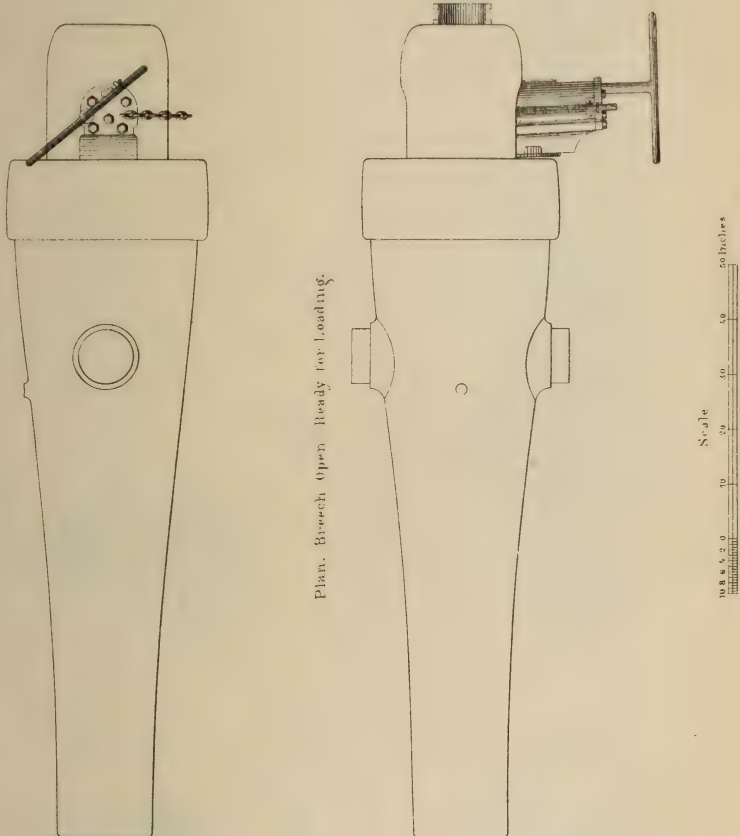
PRESSURE GAUGES.



8 INCH B. L. RIFLE.

Elevation. Breech Closed Ready for Firing.

Plan. Breech Open Ready for Loading.



8 INCH B.L. RIFLE.

Converted from a 10 inch Rodman smooth bore, by lining with a steel jacketed coiled wrought iron tube inserted from the breech jacket of tube being prolonged to the rear, and adapted for reception of the round wedge fermeture.

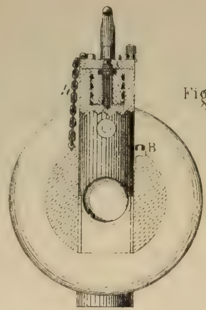


Fig. 3.

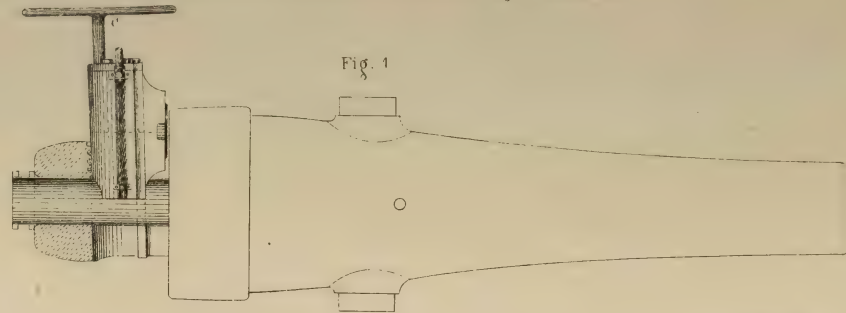


Fig. 1

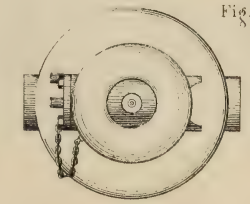


Fig. 4.

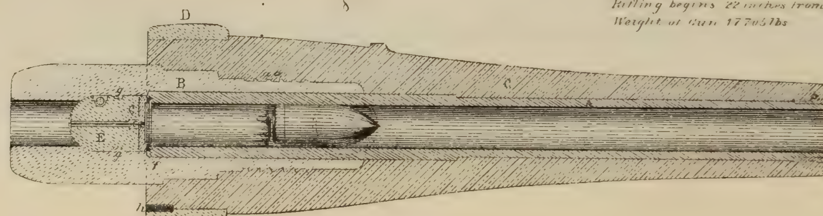


Fig. 2.

Scale.

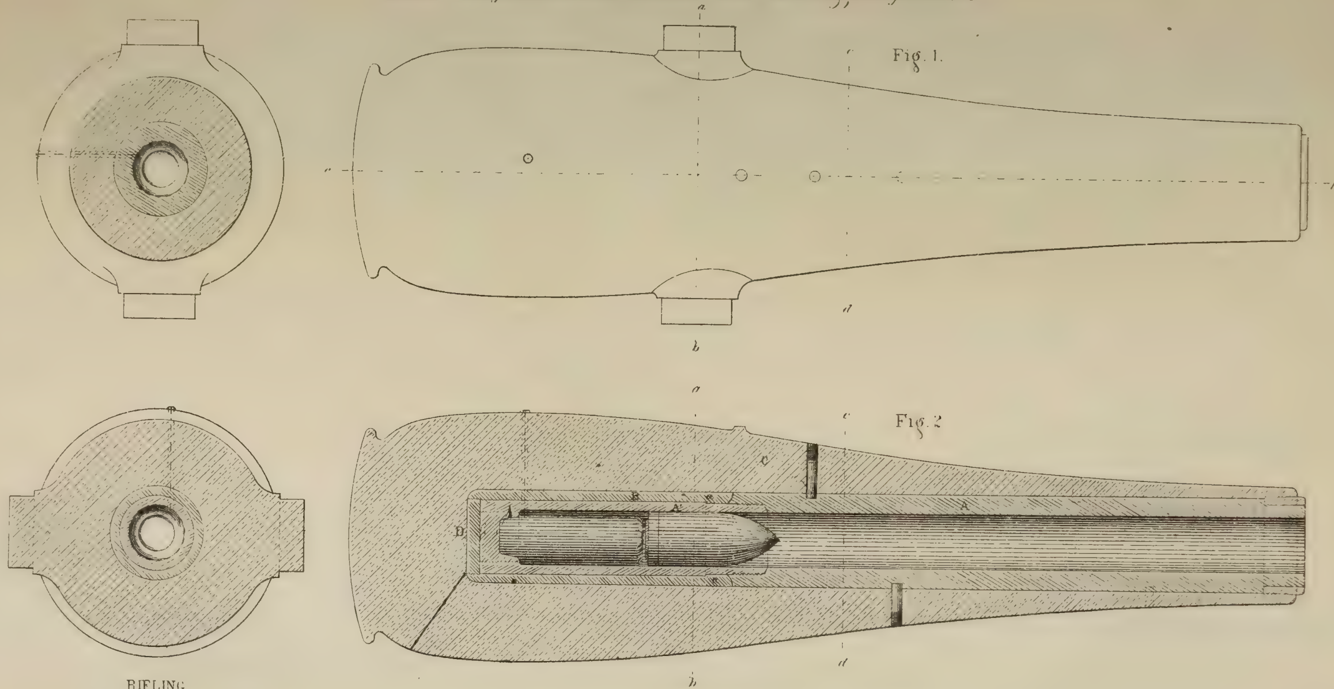
10 8 6 4 2 0 10 20 30 40 50 Inches

RIFLING.

Twist uniform one turn in 40 feet
15 Grooves and Lands each 0.83776 in wide
Grooves 0.075 in. deep
" filleted with a rad. of 0.02 in
Lands beveled " 0.01 in
Rifling begins 22 inches from bottom of bore
Weight of Gun 17705 lbs

10 INCH M.L. RIFLE.

Converted from a 13 inch Rodman smooth bore, by lining with a coiled wrought-iron tube, inserted from the muzzle (System No. 2)

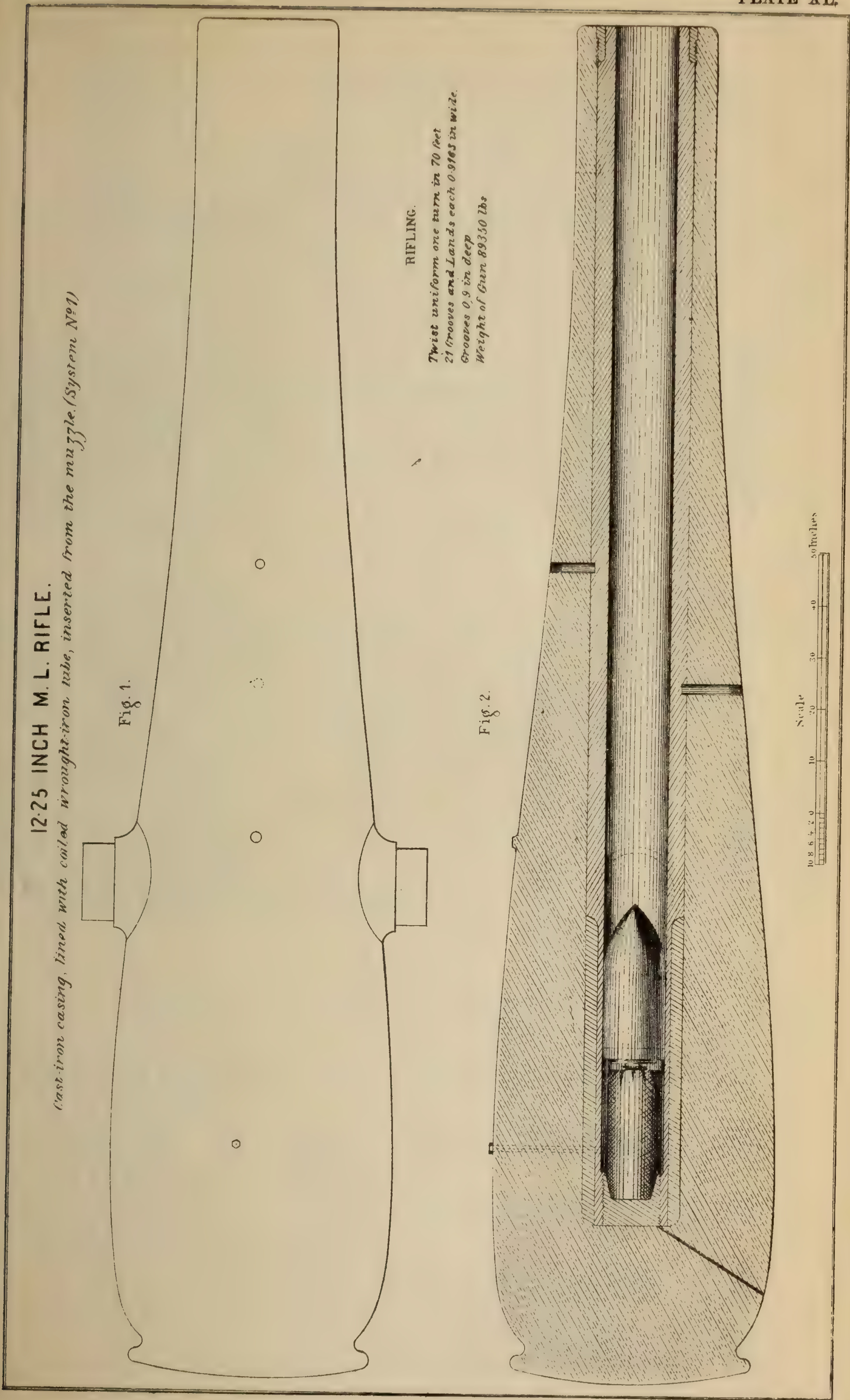


Scale

10 8 6 4 2 0 10 20 30 40 50 Inches

RIFLING.

Twist uniform one turn in 60 Calibers
17 Grooves and Lands each 0.924 in. wide.
Grooves 0.08 in deep.
Weight of Gun 40,320 lbs.


12·25 INCH M. L. RIFLE.
Cast-iron casing, lined with coiled wrought-iron tube, inserted from the muzzle. (System No. 1)
Fig. 1.
RIFLING.
Twist uniform one turn in 70 feet
21 Grooves and Lands each 0·9165 in wide.
Grooves 0.9 in deep
Weight of Gun 89350 lbs
Fig. 2.
Scale
10 8 6 4 2 0 10 20 30 40 50 Inches

APPENDIX 9a.

PROJECTILES FOR THE LAND SERVICE.

(Eighteen plates.)

TABLE OF CONTENTS.

References: Ordnance Manual; Captains Bryant and Smith, and Lieutenant Whipple, Ordnance Department.

LIST OF PLATES.

I.—SHOT, SHELL, ETC.

Nomenclature, dimensions, and weights.

Classification.—Projectiles may be classified according to their form, as spherical and elongated, the former pertaining to smooth-bore and the latter to rifled guns.

Projectiles may be further classified according to their structure and mode of operation, as *solid*, *hollow*, *case shot*, and *canister*, the different kinds according to calibers and weights.

Solid and cored projectiles.—Produce their effects by impact. They are made of cast iron, chilled cast iron, and steel. They are known as solid shot, cored shot, or battering shell.

Shells.—Under the head of hollow shot are included shells for guns, howitzers, and mortars, and grenades. They are classed according to calibers and weights, and act both by impact and explosion. The principal parts are the *cavity* for the bursting charge; the *fuse hole* through which the charge is inserted and which holds the fuse; and the *ears*, two small recesses near the fuse hole, for carrying the shell.

Case-shot.—Are a collection of small projectiles in a case or envelope. The envelope is broken by the shock of the discharge, or at any point of flight, by an inclosed charge of powder. The kinds in use are *grape*, *canister*, and *shrapnel*, or *case shot.*

Grape-shot.—A stand of grape consists of three layers of cast iron balls; a top and bottom plate; two rings for the intermediate layers; and a screw bolt and nut passing through and uniting the plates. A rope handle is passed through holes in the upper plate and secured. Used for field, siege, and mountain service.

Canister-shot.—A canister-shot consists of an envelope of metal containing layers of iron or lead balls. When tin is used for the envelope, a top and bottom plate of iron, kept in place by lapping the cut edges of the envelope over them, are employed. The top plate has a wire handle attached to it. Used for field, mountain, siege, and seacoast service.

Shrapnel, or case-shot.—The envelope is a thin cast-iron shell of about one-half the weight of a solid shot of the same caliber, filled with round lead or iron balls, held in place by melted sulphur or resin, or packed charcoal, a hole being bored, or otherwise provided, to contain the bursting charge. The fuse hole may be partially closed by a screw plug of iron with a small vent for passage of the flame to the charge. Used for field, mountain, and siege service.

Grenades.—The *hand grenade* is a small, thin, case projectile, filled with a bursting charge of powder, primed with a percussion primer. It is thrown by hand, and explodes on striking. The rampart grenades are larger shells, filled with bursting charges and short fuses. They act by their force of explosion.

SHOT.

	20-inch.	15-inch.	13-inch.	10-inch.	8-inch.	24-pounder.	12-pounder.	Remarks.
Diameter..inches..	19.85	14.86	12.87	9.87	7.88	5.68	4.52	Shot, shell, grape and canister shot, take the name of the piece in which they are used. Grape and canister are so made that a certain number will chamber in the bore.
Weight...pounds..	1,060	448	283	128	65	24.3	12.25	

	Shell.								Spherical case-shot.			Remarks.
	For S. C. guns.		For mortars.				Field guns and howitzers.					
	10-inch.	8-inch.	13-inch.	10-inch.	8-inch.	24-pounder.	24-pounder.	12-pounder.	8-inch.	24-pounder.	12-pounder.	
Diameter	9.87	7.88	12.87	9.87	7.88	5.68	5.68	4.52	7.88	5.68	4.52	The 8-inch mortar shell is used in the 8-inch siege howitzer. The 15-inch shell is 14.85 inches in diameter; it has ears at the extremities of the diameter at right angles to the fuse hole. Thickness, 2.5 inches. The fuse holes of shells and spherical case-shot for the fuse-plug taper 0.15 inch to 1 inch.
Thickness of side and bottom: True	2	1.5	2.5	1.6	1.25	0.9	0.9	0.7	0.7	0.55	0.45	
Thickness of side and bottom: Greatest	2.1	1.58	2.65	1.7	1.33	0.95	0.95	0.74	0.725	0.575	0.475	
Thickness of side and bottom: Least	1.9	1.42	2.35	1.5	1.17	0.85	0.85	0.66	0.625	0.525	0.425	
Thickness at fuse hole	3	2.25	2.5	1.6	1.25	1.35	1.35	1.05	1.5	1.1	0.9	
Depth of recess for fuse									0.4	0.4	0.4	
Diameter of fuse hole: Exterior	1.45	1.338	1.8	1.75	1.3	0.9	0.9	0.9	1.62	1.62	1.62	
Diameter of fuse hole: Interior	1	1	1.25	1.51	1.113	0.698	0.698	0.743	0.75	0.75	0.75	
Distance between ears	6	5	7	6	5							
Weight ... pounds	102	50	218	88	44	16.8	16.8	8.34	30.36	12.32	6.22	

DIAMETER OF GAUGES FOR SHOT AND SHELL.

	20-inch.	15-inch.	13-inch.	12-inch.	10-inch.	8-inch.	24-pounder.	12-pounder.	
Large ......inches.	19.90	14.90	12.90	11.90	9.90	7.90	5.70	4.53	For manner of using, &c., see inspection of shot and shell.
Small, new ...do...	19.84	14.84	12.84	11.84	9.84	7.85	5.65	4.49	
Small, old ....do...	....	....	12.80	....	9.80	7.80	5.61	4.46	

SHRAPNEL FOR RIFLED GUNS.

	4.5-inch.		3-inch.		Remarks.
	Iron.	Soft metal.	Iron.	Soft metal.	
Diameter ....inches.	4.43	4.45	2.93	2.93	Thickness at end of cup...0.25 inch.
Length ....do...	8.2	1.5	6.7	1.5	Depth of cup..............0.5 inch.
Thickness of metal at sides.....do...	.625	.15	.4	.15	Diameter of fuse hole .....1. inch.
Thickness of metal at bottom....do...	.7	.1	.3	.1	
Thickness of metal at fuse hole .do...	2.	......	2.	......	

The soft metal is attached by casting, the base of the projectile being under-cut and cross-cut. Brass sabots are attached by casting; by screwing on the base of the projectile, or forcing a sleeve over a part of the projectile prepared for its reception by grooves and chisel cuts.

GRENADES.—Six-pounder spherical case may be used for *hand grenades.* Shells of any caliber for rampart grenades, or Ketchum's *hand grenades.*

	Grape-shot.			* Canister.				
	8-inch.	24-pounder.	12-pounder.	8-inch.	24-pounder.	12-pounder.	3-inch rifle.	Mountain howitzer.
Diameter of large gauge..inch.	3.60	2.64	2.06	Lead balls.	Lead balls.	1.49	.69	.69
Diameter of small gauge...do..	3.54	2.60	2.02	11 to the pound.		1.46	Musket-ball.	
Mean weight ....pounds.	6.1	2.4	1.14			0.43		

Sawyer canisters are filled with cast iron balls; the upper end is closed with a sheet iron disk secured in place. (See Plate VI.)

For dimensions and weights of projectiles for rifled guns. (See Plates III, IV.)

Diameters of cast-iron balls from ¼ pound to 50 pounds weight.

Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.	Weight.	Diameter.
Lbs. ozs.	*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*	*Lbs.*	*Inches.*
0 4	1.231	9	4.065	23	5.531	37	6.512
0 6	1.403	10	4.211	24	5.639	38	6.570
0 8	1.551	11	4.346	25	5.714	39	6.627
0 10	1.665	12	4.474	26	5.789	40	6.684
0 12	1.701	13	4.595	27	5.862	41	6.738
0 14	1.865	14	4.710	28	5.930	42	6.793
1	1.954	15	4.819	29	6.004	43	6.846
2	2.462	16	4.924	30	6.068	44	6.898
3	2.819	17	5.025	31	6.140	45	6.951
4	3.104	18	5.121	32	6.205	46	7.002
5	3.341	19	5.215	33	6.268	47	7.052
6	3.551	20	5.304	34	6.330	48	7.101
7	3.738	21	5.392	35	6.392	49	7.145
8	3.908	22	5.476	36	6.442	50	7.198

* Cast iron balls are also used with canister.

LEAD BALLS.

Diameters of lead balls from 1 to 32 to the pound.

No. of balls to 1 pound.	Diameter.	No. of balls to 1 pound.	Diameter.	No. of balls to 1 pound.	Diameter.	No. of balls to 1 pound.	Diameter.
	Inch.		*Inch.*		*Inch.*		*Inch.*
1	1.670	9	0.803	17	0.650	25	0.571
2	1.326	10	.775	18	.638	26	.564
3	1.157	11	.751	19	.626	27	.557
4	1.051	12	.730	20	.615	28	.550
5	.977	13	.710	21	.605	29	.544
6	.919	14	.693	22	.596	30	.537
7	.873	15	.676	23	.587	31	.531
8	.835	16	.663	24	.579	32	.526

II.—SPHERICAL PROJECTILES.

Fabrication.

With the exception of grape and canister shot, which are cast in iron molds, all spherical projectiles are cast in sand. The sand used for the mold should be silicious, of an angular grain, and a moderate degree of fineness. When mixed into molding composition it should be sufficiently adhesive to retain its shape when pressed in the hand.

Case shot, shell, and all solid shot smaller than the 15-inch are cast singly. Fifteen and twenty inch solid shot are usually cast in clusters of five and three respectively. (Plate VIII.)

When cast singly, the pattern of a spherical projectile is composed of two hollow cast iron hemispheres which unite in such a manner as to form a perfect sphere; on the interior of each hemisphere is fastened a handle to enable the operator to draw it from the sand when the half-mold is completed.

The flask which contains the mold is made of iron, in two equal sections which are united at their larger bases. The other ends are fitted with movable covers. (Plate VIII.)

The operation of molding is performed by placing the flat side of one of the hemispheres on the molding-board and covering it with a section of the flask. The molding composition is then poured in, filling up the entire space between the flask and hemisphere, and is well rammed. The cover is then attached and the mold turned over, the hemisphere is withdrawn and the interior surface is painted with coke-wash and dried.

The remaining half of the mold is formed in the same way, except that a channel for the introduction of the melted iron is made by the insertion of a round stick, which is withdrawn after ramming down the composition. This channel connects with the mold by a grade at the side, in order to avoid breaking its surface with the falling metal.

Hollow projectiles.—Thus far the operations of molding and casting solid and hollow projectiles are the same. The cavity of a hollow projectile is made by the insertion of a *core*. This is a sphere of the proper size, made by compressing molding composition by means of a core-box on a hollow iron stem or spindle.

The *core-box* (Plate VIII) consists of two hemispherical cups. The lower one is made in two sections, which are so constructed as, when united, to receive and hold the spindle in place, and also to form a base for the core-box to rest upon while being filled.

The core is formed by pouring the composition into the opening at the top of the upper cup and ramming it down until the interior space is filled. The surface at the opening is then rounded off with a former, and the core-box is removed. The core is then thoroughly dried in an oven and afterward painted with coke-wash.

The core is centered in the mold by means of a gauge and is supported in that position by the spindle which forms the fuse hole. The spindle is perforated with small holes to allow the escape of steam and gas generated by the heat of the melted metal; that part of it which forms the fuse hole is coated with sand to prevent adhesion.

When the ears for the shell-hooks are cast in the projectile the necessary projections for their formation are placed in position before drying the mold.

In pouring the melted iron into the mold with the ladle, care should be taken to prevent scoria and dirt from entering with it, and for this purpose the surface should be skimmed with a stick of wood.

After the iron has become sufficiently hardened the flask is removed, the sprue-head is broken off, and the composition scraped from the outside of the casting. The core is then broken up and removed, and the interior surface cleaned by a scraper. The projection at the gate and other excrescences are next chipped off and the surface of the projectile is smoothed in a rolling barrel, or with a file or chisel if necessary. The fuse hole is then reamed out to the proper size and the projectile is ready for inspection.

Cluster shot.—When shot are cast in clusters, the pattern is made of wood and consists of two longitudinal halves (Plate IX), which are fitted with iron pins or dowels so that they can be accurately joined together for the construction of the mold.

The cluster is cast with a sinking head to feed the shrinkage, while the shot are made with a diameter slightly in excess of the required one, to permit of their being turned down and finished.

The flask (Plate IX) is also made in two equal parts or sections which are united by bolts. The back of each section is fitted with movable plates to admit of the introduction of the molding composition.

To form the mold one-half of the pattern is laid upon the molding-board, together with the pattern for one-half of the channel for the metal, both being held in place by dowels. A section of the flask is then placed in position over the patterns and the intervening space is filled with molding composition, which is firmly rammed down, the patterns for the branches to the channels being introduced as the work progresses. The plates are then attached in their places. To form the other section of the mold, the finished one is removed from the molding-board and turned over, the remaining halves of the patterns and flask are placed in position upon it, and the molding composition filled in in the same manner. A layer of dry sand is first sprinkled over the surface of the finished section to prevent adhesion.

The mold being completed, the two sections are separated and the patterns withdrawn. After being thoroughly dried in an oven and receiving a coating of coke-wash on the interior surface, the sections are united and firmly secured together with bolts and nuts. The mold is then ready for the casting and is lowered into the pit.

Several clusters are usually cast with one heat of metal, the number depending upon the capacity of the furnace.

The casting is usually allowed to remain in the pit for twelve or fifteen hours after the pouring of the metal, when it is hoisted out and taken from the flask. After it becomes cool it is freed from the adhering composition and the gates are broken off.

To separate the shot in the cluster, the latter is placed in a lathe, the sinking-head being secured in the chuck at the head of the machine, while the other end is supported by a movable center which slides upon the ways. When the cluster is properly centered, the necks which connect the shot are turned down as small as it is safe to make them without risking the breaking of the cluster in the lathe.

The neck nearest to the bottom is then carefully turned down until it begins to show indications of breaking. The cluster is then chocked up by placing blocks between it and the lathe-bed, the center is slid back, and the shot is broken off by blows with a hammer and removed. The cluster is then recentered in the lathe, and the shot are successively detached in a similar manner until all are separated.

Care should be taken to preserve, as far as practicable, a spherical form to that portion of the surface where the neck is turned away. The small portions of the necks which remain after the separation are chipped off by hand.

The shot is next placed in the *shot lathe* (Plate X), where it is turned down to the required diameter and given a smooth and finished surface. The tool-rest of this lathe is attached to a geared wheel, which is pivoted in a horizontal position upon an iron frame secured to the lathe-bed. The motion of this wheel by means of a feed causes the edge of the tool to move on the arc of a circle, its distance from the center of the circle meanwhile being regulated by a screw in the base of the rest. The shot is centered in the lathe by means of a square-headed screw in the axis of the wheel.

In turning the shot it is made to revolve upon that diameter which coincides with the axis of the lathe, while the movement of the tool-rest, as above described, brings the tool in contact with all of the surface which is not covered by the supports.

In this position the shot is finished as far as practicable, and is then recentered so that the unturned portions of the surface can be brought in contact with the tool, when they are finished in like manner.

The ears for the shell-hooks are then drilled in a drilling machine and the shot is ready for inspection.

Fifteen-inch and 20-inch shell are sometimes cast above size and finished in the shot-lathe in the same way as cluster shot.

Inspection of spherical projectiles.

(Plates XV, XVI.)

SHOT.

The inspecting instruments required are one *large* and one *small gauge* and one *cylinder-gauge* for each caliber. The cylinder-gauge has the same diameter as the large gauge; it is made of cast iron and is five calibers long. The large and small gauges are made with a difference in diameter of 0.02 inch for projectiles turned in a lathe, and 0.04 inch for those not so turned. All these gauges should be verified from time to time, and when they have become 0.01 inch larger than their true diameter they should no longer be used.

One *hammer* having a flat face and a conical point.

One *searcher* of steel wire.

One *cold-chisel.*

Steel punches.

Figure-stamps.

The shot should be inspected before they become rusty; after being well cleaned each shot should be carefully examined to see that its surface is smooth, that the metal is sound and free from seams, flaws, and blisters. If cavities or small holes appear on the surface, strike the point of the hammer or punch into them and ascertain their depth with the searcher; if the depth of the cavity exceeds 0.2 inch, the shot should be rejected. The discovery of any attempt on the part of those engaged in the fabrication of the shot to conceal such defects by filling up the holes should insure rejection.

The shot must pass in every direction through the large gauge and not at all through the small one, and the mean of their diameters should be nearer that of the former gauge than of the latter.

After having been thus examined, the shot are passed through the cylinder-gauge, which is placed at an inclination of about two inches between the two ends, and supported on blocks of wood in such a manner as to be easily turned from time to time to prevent its being worn into furrows. Shot which *slide* or *stick* in the cylinder should be rejected.

The average weight of shot of 10 inches and under is deduced from that of three parcels of 20 to 50 each, taken indiscriminately from the pile; some of those which appear to be the smallest should be also weighed, and if they fall short of the prescribed weight of their caliber by more than one thirty-second part, they should be rejected. Shot of larger caliber than 10 inches should each one be weighed by itself and its weight stamped upon it near one of the ears for the shell-hooks.

GRAPE AND CANISTER SHOT.

The dimensions are verified by means of a large and small gauge attached to the same handle. The surface of the shot should be smooth and free from seams and cavities.

SHELLS AND CASE SHOT.

The following inspecting instruments are required in addition to those used in inspecting shot, viz:

Calipers for measuring the thickness of the projectiles at the side.

Calipers for measuring the thickness at the bottom.

Gauges for the dimensions of the fuse-hole, and for the thickness of metal at the fuse-hole.

A pair of hand-bellows; wooden plugs to fit the fuse-hole and bored through to receive the muzzle of the bellows.

The surface of the shell and its exterior dimensions are examined as in the case of shot, particular attention being paid to the hemisphere opposite the fuse-hole. Cavities and imperfections in casting are generally found about 30° from the top of the shell when in the position in which it was cast. Shells should be rejected for rough casting, projecting seams, sand-flaws, a collection of dross, cavities or honey-combs of more than two-tenths of an inch in depth, whatever their diameter, or a number of small holes giving the projectiles a spongy appearance.

The shell is next struck with the hammer to judge by the sound whether it be free from cracks; the position and dimensions of the ears are verified. The thickness of the metal is then measured at several points on the great circle perpendicular to the axis of the fuse-hole. The diameter of the fuse-hole, which should be accurately reamed, is

then verified, and the soundness of the metal about the inside of the hole is ascertained by inserting the finger.

The shell is now placed upon a trivet in a tub containing water deep enough to cover it nearly to the fuse-hole; the bellows and plug are inserted into the fuse-hole, and the air forced into the shell. If there be any holes in the shell, the air will rise in bubbles through the water. This test also gives another indication of the soundness of the metal, as the parts containing cavities will dry more slowly than the other parts.

The mean weight of shells of 10 inches and under is ascertained in the same manner as that of shot, and larger ones should be weighed and stamped the same as with shot of like caliber.

All projectiles rejected in the inspection should be marked with an X made with the cold-chisel; on shot near the gate; or, when turned, near one ear, and on hollow projectiles near the fuse-hole.

III.—OBSERVATIONS ON THE MANUFACTURE OF CAST-IRON PROJECTILES.

Projectiles, for field artillery, should be made of a lively gray iron, having a tenacity of 18,000 to 20,000 pounds per square inch, and that runs sound and presents a smooth even surface, and not too hard to ream with moderate facility when cast into shells and case-shot.

Battering shot, for siege artillery, should have a tenacity of 23,000 to 24,000 pounds per square inch, and be made of iron that runs sound and smooth.

Elongated shot, for rifled guns, should be cast on end, forward end downward.

Elongated shells and *case-shot* should be cast on end, rear end downward.

Eight-inch and 10-inch shells, for both guns and mortars, and 13-inch mortar shells, should show incipient mottle, and have a tenacity of 22,000 to 23,000 pounds per square inch, without being too hard to ream with moderate facility.

The *recesses* of the shell-hook holes should be *cast*, but the *holes* themselves should be *drilled*.

Eight and 10 inch solid shot and 15-inch shells should show a fine mottle when broken, with a tenacity of 23,000 to 24,000 pounds per square inch, and not too hard to ream; the limit of hardness of shells being when they become too hard to ream.

Fifteen-inch solid shot should show a decided mottle, and have a tenacity not less than 25,000 pounds per square inch.

Fifteen-inch shot and shell should both be cast in dry-sand molds, with large "risers," which should be filled with hot metal and kept open as long as possible.

The metal, especially in casting large projectiles, should be poured as cold as may be compatible with sound castings.

All shot should be cast of iron that contracts but little in cooling, there being quite a difference in this respect in the different varieties of iron.

Samples for tenacity of metal in shells, and all calibers of solid shot below 8″, should be cast on end, and in the same kind of molds (*i. e.*, green or dry sand), and poured from the same ladles of metal as the projectiles themselves.

The finished diameter of samples for tenacity of field projectiles, at point of rupture, should be 1.128 inch.

For all calibers of solid shot of 8-inch and upward, the samples for tenacity should be taken from the projectiles themselves. This can be most readily and economically done by means of a hollow drill that will take out a sample of 2 inches in diameter and 3½ inches long.

Samples for siege projectiles and large shells will be 2¼ inches in diameter and 10 inches long.

Twenty-inch shot should be of the best quality of gun iron, and be cast in a dry-sand mold, and be finished to their true dimensions by turning.

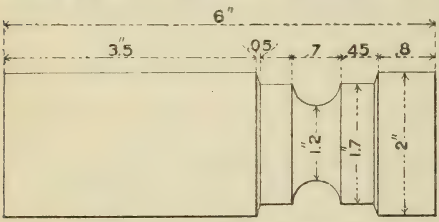
For 13-inch shot, tenacity of the iron should be about 28,000 pounds; density not less than 7.270. They should be cast in dry-sand molds, with "risers" of 8.66 inches diameter and 12 inches high.

Fifteen-inch solid shot, manufactured at South Boston in 1867, of 75 per cent. of remelted gun iron and 25 per cent. of No. 1 charcoal pig, had a mean density of 7.2730 and tenacity of 34,000 pounds.

Twenty-inch shot, manufactured in 1865 at South Boston foundry, were cast vertically in clusters of three, with "risers" of 16 inches diameter and 3 feet 6 inches in height. The test specimens taken from the "risers" next to the shot gave a mean density of 7.2850 and tenacity of 31,500 pounds.

The finished diameter of samples for tenacity of field projectiles at point of rupture should be an inch.

For all calibers of solid shot of 8-inch and upward, the samples for tenacity should be taken from the projectiles themselves. This can be most readily and economically done by means of a hollow drill that will take out a sample of 2 inches diameter and 3½ inches long.



Drawing of samples for tenacity of field projectiles is hereto appended.

Samples from siege projectiles and large shells will be 2¼ inches in diameter and 10 inches long.

Where Bormann fuses are used the fuse and fuse-plug holes are cylindrical.

IV.—PROJECTILES NOT ADOPTED AS STANDARD, BUT SUBJECT TO ISSUE.*

Butler projectile.—(Plates V, VII.)

This projectile consists of a cast-iron body having a double-lipped expanding ring attached by a screw-thread to its base. Upon discharge, the powder gases entering the cannelure of the ring expand the outer lip into the grooves communicating rotation to the projectile, and pressing the inner lip tightly against the base of the projectile, tends to prevent stripping. The ring may be of brass (75 parts of copper to 25 of tin) or of an alloy of copper, tin, and brass, the brass being fused with the copper.

The *Butler canister* consists of a hollow cylinder made up of truncated iron wedges inclosed in an envelope of tin. The cylinder is closed at the bottom with a lead cup inclosing a disk of wood, and at the top with a sheet-iron plate, disks of tin being employed on the outside at both ends to facilitate soldering. The interior of the cylinder is filled with the round iron balls.

* No projectile has as yet been adopted as the standard.

Arrick ("Eureka") projectile.—(Plates VI, VII.)

This projectile consists of a cast-iron body having a conical base, to which is attached a sabot combined of an annular key and a concave and convex disk.

Upon discharge, the ring is flattened out against the base of the projectile, and takes the impression of the grooves, communicating rotation to the projectile; at the same time the annular key is driven forward upon the base, filling the space between the projectile and the lands, and is claimed to center the base of the projectile. The sabot is prevented from turning on the projectile by a series of flanges cast on the base, which fit into recesses on the sabot, and from stripping by means of a strong bolt screwed into the base of the shot.

Dana projectile.—(Plate VII.)

This projectile consists of a cast-iron body having a conical base, to which is attached a cup-shaped ring of brass.

Upon discharge, the ring is driven forward upon the base, and by this movement the soft metal is expanded into the grooves and rotation communicated to the projectile.

As the front end of the sabot passes the shoulder it is crowded down into the groove cut round the body of the shot, and thus "clinched," as it were. The same end is sought in the arrangement at the bottom of the sabot, where the gas, acting in the cannelure, presses the lip into the groove cut in the cast iron. Such is the provision designed to secure the sabot from stripping.

Turning upon the projectile is prevented by wedge-shaped projections and recesses upon the base of the projectile and the under surface of the sabot.

Parrott projectile.—(Plates V, VII.)

Captain Parrott's projectile is composed of a cast-iron body and a brass ring cast into a rabbet formed around its base. The flame presses against the bottom of the ring and underneath it, so as to expand it into the grooves of the gun. To prevent the ring from turning in the rabbet the latter is recessed at several points of its circumference.

Parrott's incendiary shell has two compartments formed by a partition at right angles to its length. The lower and larger space is filled with a burning composition; the upper one is filled with a bursting charge of powder, which is fired by a time or concussion fuse. The burning composition is introduced through a hole in the bottom of the shell, which is stopped up with a screw-plug.

A more recent form of the Parrott projectile for large calibers is shown in Plate VII. The sabot is cast on to the projectile, and is provided with a lip and cannelure. It is prevented from turning on the projectile and from stripping by means of recesses and undercuts upon the base of the projectile, into which the metal when liquid enters.

Hotchkiss projectile.—(Plate VI.)

The Hotchkiss projectile is composed of three parts—the body, the expanding ring of lead, and the cast-iron cup.

The action of the charge is to crowd the cup against the soft-metal ring, thereby expanding it into the rifling of the gun. The time-fuse projectile has deep longitudinal grooves cut on its sides to allow the flame to pass over and ignite the fuse.

The last rifle projectile submitted by Mr. Hotchkiss has an expanding-cup of brass attached to its base in a peculiar manner. The cup is divided into four parts by thin projections on the base of the projectile. This arrangement is intended to facilitate the expansion of the cup and to allow the flame to pass over to ignite the fuse.

(*Dyer projectile.*—(Plate V.)

This projectile is composed of a cast-iron body and a soft-metal expanding-cup attached to its base. The adhesion of the cup is effected by tinning the bottom of the projectile and then casting the cup on to it. The cup is composed of an alloy of lead, tin, and copper in certain proportions.

A corrugated cap of tinned sheet iron was used with 3-inch projectiles to catch and direct that portion of the flame of the charge which escapes over the projectile on to the fuse to ignite it.

Absterdam.—(Plate VI.)

The sabot is made of brass, which becomes malleable when heated. The brass is cast into a groove on the base of the projectile, larger at the bottom than at the surface of the projectile, the sabot being thus dovetailed in place.

The Sawyer canister.—(Plate VI.)

The Sawyer canister shot consists of a casing, A, of malleable iron, in one piece, in the form of a hollow cylinder, having one end closed by a head cast therewith, through which head is forced one or more small holes, *a*, through which a portion of the gas occasioned by the explosion of the charge of powder enters, driving forward the small iron balls and disengaging the metal cover *b* placed in the forward end of the casing to hold the contents in position till fired. The casing has cut through its walls one or more series of oblique slits, *c c*, the end of each slit slightly overlapping the end of the next slit in the same series, thus nearly severing the casing into two or more sections; said sections being held only by the narrow bars of metal *d d* between the contiguous ends of two slits, *c c*, as shown in the figure; which bars are sufficiently strong to withstand the ordinary shocks of handling and transportation, but not strong enough to resist the shock of the explosion of the charge of powder in the gun; so that when the shot is discharged from a gun the cover *b* is stripped from the mouth of the casing, and the casing is broken into two or more sections, from which the small shot *e* are more readily and completely discharged than they would be if the casing remained intact, and each of said sections of the shell serve as a solid shot, doing greater execution than could be done were the shell to remain in one piece.

V.—THE FABRICATION OF RIFLED PROJECTILES.

Shot and shell should be made of gray or mottled iron of good quality, varying, however, with the kind and size of projectile required.

The largest have generally been made from gun metal, melted in an air-furnace, but ordinary sized projectiles from mottled iron produced by melting in a cupola furnace, a mixture of white and gray pig iron.

For chilled shot a mixture is used of about one-half No. 2 or 3 cold-blast charcoal iron with the same amount of No. 1 or 2 American anthra-

cite pig; but, as a matter of economy, the former is frequently replaced by old shot metal, and the latter by old car wheels, the percentage of each being determined by experiment.

Plate XI represents the McKenzie *cupola furnace*, which is oval in shape; Figure 1 being a section through its shorter and Figure 2 a section through its longer axis.

The body of the cupola consists of a lining of fire-brick inclosed in a wrought-iron caisson, contracted at the top to form the stack, and resting on a cast-iron bottom plate, which is supported on iron pillars.

The peculiarity of this cupola, as compared with others of the many varieties in use, exists only in the shape of the tuyere, or in the method employed for introducing the blast, a continuous air-chamber inclosed between the caisson and a wrought-iron apron, which projects inward, and is braced by a cast-iron ring, which can easily be replaced when worn out. The tuyere itself is the slot beneath, through which the air, admitted to the chamber from the blast-pipes, passes into the cupola.

The bottom is a cast-iron drop-door made in two hinged parts, and supported, when closed, by a prop. This bottom is covered with a layer of sand, arranged with a gentle slope towards the spout; the latter, through which the melted iron runs to the ladle, is of iron coated with loam, and painted with coke-wash.

The charging-door is at the rear of the furnace, and the stock is generally lifted to it on an elevator. To charge the furnace, shavings are placed in the bottom, then light wood, and cord-wood sawed into lengths of from ten to eighteen inches, a part of it being stood on end around the sides to protect them, and the whole bed being built up level. In this last respect care is used through all the subsequent stages of the charging. On the top of the wood is placed the "stock," which, for a No. 8 furnace, consists of about 2,100 pounds of (Lehigh) lump coal. The fire is then lighted, and when the flames are seen to be working well through the mass about five tons of iron are placed evenly on top; then about 900 pounds of egg or grate coal, followed by five tons of iron. This "building up" of the charge can be continued as long as the material can be handled through the charging-door, the ordinary capacity of such a furnace as described being about fifteen tons. In charging the iron, it is usual to first put in pieces of plate and light scrap iron to protect the lump coal from being broken as the heavier portions of the charge are added. As soon as the cupola is "charged" the blast is put on, and in about twenty minutes the iron is "down," and ready to be drawn off. Warned of this by the melted metal "blowing" through the "tap-hole," the melter closes it with a "*bod*" made of sand mixed with clay-wash; he has prepared also a number of other "bods," which he uses for the same purpose whenever it may be necessary while drawing the metal. The "bod" is lightly attached to the end of an iron or wooden rod, and being shoved into the tapping-hole, sticks to it and closes it up.

To "tap" the cupola, the melter shoves into the "bod" an iron bar with a square point, and enlarges the hole by turning the bar around.

The ladles into which the metal is run are lined with a mixture of molding sand and clay-wash, or with loam, and thoroughly dried before being used.

When all the metal is drawn off, the cupola is "dumped" by removing the prop and allowing the doors to fall. The "dump" is then extinguished, and the pieces of iron and fuel picked and sifted out.

After each day's casting, the furnace has to be repaired by picking out the slag which has formed within, and by daubing with a mixture

of clay and fire-sand the parts of the lining where the fire-brick has been burned out. About once in six months the entire fire-brick lining has to be replaced.

Projectiles are cast in sand with which has been mixed a sufficient amount of clay-water to make it adhesive enough to retain its shape in molding. The sand used is a mixture of about 0.8 fine sand to 0.2 loam or field sand. If the mold is dried in an oven until its surface is deprived of its moisture, the casting is called a "dry casting"; otherwise, a "green casting."

The following description refers to the cored shot with chilled head, but since all large oblong shot are now cast hollow it applies, with slight variations (which are noted as they occur), to all shot and shell of this class.

The *pattern* (Plate XII, Fig. 1) is made of hard wood and in two parts, the larger for the body of the shot, the smaller for its base. A handle is screwed into the bottom of each for convenience in extracting them from the molds. The pattern is about $0''.4$ larger in diameter than the true size of the shot, to allow for the shrinkage of the iron in cooling (from $\frac{1}{10}$ to $\frac{1}{8}$ of an inch to the foot), and to secure sufficient metal to enable the shot to be properly finished.

The *core-box* (Plate XII, Figs. 2 and 3) is made of cast iron in two sections, which can be fitted and fastened together by a screw-clamp. The holes in the flanges, as represented in drawing, are for the bolts used for securing the parts together while being bored out, and for the "steadying-pins" when they are united in molding. The head of the box is closed with an iron plug. The core is formed about an iron tube closed at one end and perforated with small holes to allow the escape of steam and gas generated by the heat of the melted metal. Twine is wrapped around the tube over the perforations to protect them, and that portion of the iron which is exposed is coated with sand.

The sections of the box being apart, the tube at its open end is fitted into a seat at the base of one section and covered by the other. The box is then closed tight with the clamp, stood upright, and filled and packed through the top with a mixture of about one-third fire-sand to two-thirds loam. The head is formed of sand of more adhesive quality, which is generally produced by the addition of a little flour, and the cap is fitted and hammered into place. The clamp is then unscrewed and taken off, the box laid on its side, the cap and upper section removed, and the lower one tapped with a mallet to release the core, which is carefully lifted from its bed and placed on loose sand. It is then dried in an oven, painted with coke-wash, and redried.

The *flasks* (Plate XII, Fig. 4) are made of cast iron in two parts, the bases of which are to be in contact being provided with evenly-faced flanges. In fitting the sections together, pins in the flange of one pass through holes in the flange of the other, and the flasks are further secured by clamps which are driven over the united flanges. Each section is provided with projecting handles. Fig. 5 represents the iron cross-bar which supports the core, and which is shown in cross-section in Fig. 4. It is riveted to the inside of the flask.

Molding.—The lower part of the pattern is then stood on a board, with the base down, and covered with its flask; on the head of the pattern is placed the chill-mold, which is of cast iron and shaped on the interior like the head of the projectile (Fig. 4). Sand is poured into the flask and well rammed about the pattern. A channel called "the feeder," for the introduction of the metal, is formed by packing the sand about two sticks which unite within the body of the mold. The filled flask is then

inverted, and its upper base slightly sprinkled with dry sand, called by the molders "parting sand," which prevents the adhesion of the two sections of the mold. The smaller part of the pattern is fitted to the base of the larger and covered with its flask. Sand is poured in as before, and a short channel called the "riser," and the continuation of the "feeder," formed with sticks as before. The sticks are drawn from the smaller part of the flask, the flask itself separated, and the pattern withdrawn by means of the handles screwed into the bases. The chill-mold is left in the sand, the sticks for the "feeder" are withdrawn (the smaller from the inside of the mold), and the molder repairs any damage which may have occurred during the operation.

Fig. 6, Plate XII, represents a wooden templet shaped like the head of the shot, to the base of which is screwed an iron strap; this strap is bent back at each end so as to form two arms, in each of which are round holes corresponding to the position of the "shell-hook holes." The templet is then placed in the mold, and an iron pin pushed through the holes into the sand 0''.75 deep. Into the "prints" thus formed are fitted two little cylinders of sand, 1''.5 long and 0''.5 in diameter, which have been previously molded, painted with coke-wash, and dried. The core-stem is then fitted to its seat and screwed fast, and the entire mold coated with coke-wash and dried. Both of these operations require careful attention. Should the dried portion of the mold extend too deep into the sand, which would happen if more than the proper amount of the wash were absorbed, the sand would peel off during casting and get incorporated with the metal, and produce, besides, excrescences on the surface of the casting. The drying is sometimes performed in an oven; otherwise, little charcoal fires contained in iron pans are suspended in the cavity. The coating is generally done by hand, but in shells and ordinary shot without chilled heads, when cast, as is customary, with head up, a tin *funnel* (Fig. 7) is sometimes used, which facilitates the operation, and effects a saving in the amount of wash required. The molds of projectiles so cast have a channel running from the head as a "riser" for the metal in the case of shot, and a seat for the core-stem in the case of shells.

The spout of an ordinary funnel is inclosed in a cylinder slightly less in size than the cylindrical part of the mold, and the space between the end of the spout and the lower base of the cylinder also closed tight with tin. A smaller funnel with a closed spout is attached by straps to the cylinder.

The mold of the body of the shot is placed on a bench with a bucket beneath, and the "funnel" is so introduced into it that the lower spout fits into and closes the hole in the head. An amount of coke-wash previously determined as sufficient is poured into the open funnel, and, falling, is prevented from injuring the mold by striking the closed funnel beneath. The wash rises about the surface of the cylinder and only in the space between it and the sides of the mold, and when the molder sees it reach the top of the mold he lifts out the funnel and the wash escapes through the head of the mold into the bucket beneath. The wash is used over and over again, addition being made each time of sufficient to compensate for the amount absorbed by the previous mold.

The larger section of the flasks is then placed on the ground with the head down (for chilled shot) and leveled, the smaller section placed on top and keyed to it, and the molder completes the mouths of the "feeder" and "riser." As before stated, it is customary to cast shell and shot without chilled heads, with the base of the mold down; and the differences between the operations of casting them and those de-

scribed consist only in the necessary alterations of the parts of the mold to adapt it to the reverse position of the pattern, and, with shell, in the fact that the core is larger, and that the stem is secured at each end.

Casting.—The metal is run from the cupola into ladles, and, in the case of chilled shot, usually slightly cooled by throwing in a piece of scrap iron. This is done to prevent the chill-molds from being cracked. The metal enters the mold from below, near and above the chill mold, and (from the shape of the lower branch of the "feeder") in an oblique direction, to avoid disturbing the core and to give a circular motion to the metal as it rises in the mold, and so prevent the scoria from adhering to the sides. One workman skims the surface of the metal with a wooden stick, as it runs from the ladle, to prevent the admission of the scoria, while another stirs it as it rises, with an iron rod, through the "riser," to bring the impurities to the surface. Before fairly cooled, the flasks are removed, the sand knocked off, the core-stem extracted, and the shot left to cool in the heated sand in which it was cast.

Finishing.—The sand is first carefully scraped from the cavity, the sinking-head removed, and the rough edges trimmed off with a cold-chisel. It is then examined as to quality and weight, and the amount of eccentricity roughly determined. The shot is at once condemned if there be a variation in any of these particulars in excess of that allowed. It sometimes happens, too, that the chill has extended so far over the surface as to make it impossible to finish the shot by the means ordinarily employed in this country. Such shot are, however, sometimes finished by the grindstone. Having passed this preliminary inspection, it is put in a lathe and turned down to the true diameter for a length of 0.25 inch.

The *finishing-press* consists (Plate XIII) of a steel die, supported on a hollow iron platform resting upon the head of an hydraulic ram which is worked by a steam-pump. On the left of the press is a handle for opening the valve to allow the admission of the water to the cylinder, and an automatic device for closing it and opening the valve for the escape, when the ram has reached its proper stroke. There are four iron guides for the hollow platform, connected at top by an iron cross-head, through the center of which passes a heavy screw; the end of the screw is hollowed out to the shape of the head of the shot, for which it forms a support. Iron tongs (represented in *a a*) are used for raising the shot from the floor to its seat, and are raised and lowered by the movement of the "press" itself. Two workmen are required for the machine, and two cuts are taken on each shot; the smaller die being the true size of the shot, and the other slightly larger. Supposing one shot to have been fitted into the die for the short length turned down in the lathe and its head inserted in the end of the screw, another is stood upright on the floor. One workman then opens the valve, while another guides the descending tongs over the head of the shot below, as the hollow platform and die moves up. When the tongs have reached the center of the shot below they are clamped. As soon as the die has passed over the cylindrical part of the shot, the latter falls through the hollow platform into sawdust below; the automatic device then releases the ram, which descends, and raises the tongs with the shot which is attached, and which is guided into its seat by the workmen. With this machine a thousand shot can be turned out per day. The dies, which are made of American steel, will last for about 1,000 shot without resetting. The same operation is oftentimes performed entirely in the lathe, but is very much less rapid than that just described. The

shot is then placed in a lathe and the base finished; if the Butler sabot is to be used, a screw thread is cut upon the base. The sabot is usually formed of an alloy of 70 parts copper and 30 of zinc. It is either cast separately or directly upon the base of the projectile; in the former case it is bored and turned to the finished size. The shot is completed by tapping a thread on the screw-plug hole; fitting it with a plug, and screwing or casting on the sabot.

Inspection.—The following table shows the points upon which the inspecting officer must inform himself and report before accepting shot, and the variations he is authorized to allow:

Subject of measurement.	Prescribed dimensions.	Allowed variations.
Projectile:		
Length of cylindrical portion of body		±0.4
Length of head		
Length of base for sabot		±0.5
Total length of projectile		+ .15 − .1
Diameter of cylindrical portion		±0.2
Diameter of base over threads		± .01
Pitch of threads		0
Radius of head		± .05
Thickness of bottom		.1
Length of interior cavity		± .1
Thickness of walls at —— inches from ——		
Thickness of walls at —— inches from ——		
Eccentricity of axis of interior cavity at —— from base		0.1
Diameter of fuse (or screw-plug) hole		± .01
Pitch of thread on fuse (or screw-plug) hole		0
Length of thread on fuse (or screw-plug) hole		± .1
Diameter of hole for shell-hooks		± .01
Depth of hole for shell-hooks		± .05
Distance from base of projectile		± .02
Weight of projectile, pounds		± 2
Sabot:		
Height of sabot		± .02
Exterior diameter of sabot		± .02
Interior diameter of sabot		± .01
Maximum thickness of outer lip		± .01
Minimum thickness of outer lip		± .01
Depth of cannelure		± .03
Maximum width		± .01
Weight of sabot		
Weight of sabot and projectile, pounds		± 2

No. of —— inch —— examined		Weight of total number accepted	
No. rejected for erroneous dimensions of head		Mean weight of projectile	
No. rejected for erroneous dimensions of cylindric body or base		No. of sabots examined	
No. rejected for erroneous dimensions of interior cavity		No of sabots rejected for erroneous dimensions	
No. rejected for eccentricity of interior cavity		No. of sabots rejected for defects in material or finish	
No. rejected for defects in material or finish		Total number of sabots rejected	
Total number rejected		No. of sabots accepted	
Total number accepted		Weight of total number accepted	
Weight of heaviest one accepted		Mean weight of sabot	
Weight of lightest one accepted		Weight of total number of shot and sabots accepted	

The instruments used are as follows:

1. One large ring-gauge, with handle; interior diameter 0″.03 less than the diameter of bore of gun.

2. One small ring-gauge, with handle; interior diameter 0″.07 less than the diameter of bore of gun.

3. One cylinder gauge made of cast iron and five calibers in length; interior diameter same as large ring.

4. Calipers (Plate XIV, Fig. 1) for measuring the thickness of the walls of the shot or shell and determining the eccentricity. This instrument consists of two parallel arms, formed by a continuous steel strap. One arm is terminated by a curved point, and is graduated into inches and quarters, from the end towards the center; the other arm carries a socket, at right angles to its length, through which slides a graduated measuring-rod. The zero of the scale corresponds to the position of the rod when it is in contact with the curved point, and a vernier scale on the socket permits measurements to 0″.01.

To use the instrument, the arm with the curved point is inserted into the cavity through the screw-plug hole, and the clamp *a* screwed fast at the required point. Two short cylindrical arms on the clamp serve as bearers, and allow a motion of the instrument only on its own plane.

The eccentricity of a spherical projectile is measured by the distance of the center of gravity from the center of figure. In oblong shot, however, it varies directly for each cross-section from the seat of the core, which is near the screw-plug hole, to the head of the cavity, and is measured by the angle made by the axis of the cavity with the axis of the projectile.

To determine the axis of the cavity, the greatest and least thickness of the walls are measured at two or more depths. Half the difference between the two will give the distance between the axis of the cavity and that of the projectile for that particular section. It is ordinarily considered sufficient, however, to determine the eccentricity of but one cross-section near the center of the gravity and compare it with the known results of previous experiments.

5. The first intimation of eccentricity is shown upon the *rolling table*, which consists (*b b* Plate XIV, Fig. 1) of a heavy cast-iron plate, beveled with great care, and two parallel rails attached to it and separated from each other by a distance slightly less than the length of the cylindrical part of the shot.

When a shot is rolled upon the rails, the heaviest side must come to rest beneath, and a more or less readiness to assume a particular point of rest indicates approximately the amount of eccentricity.

6. *Measuring-rod* (Plate XIV, Fig. 2), for determining the length of cavity; made of steel and graduated into tenths of an inch for a short distance on each side of the point indicating the proper length.

7. *Gauge* (Plate XIV, Fig. 4), for length of screw-plug hole; made and graduated like the preceding.

8. *Templet* (Plate XIV, Fig. 3), for gauging the profile of the shot; made of steel; graduated to indicate the length of head, position of shell-hook holes, length of cylindrical part, and total length.

9. *Gauge* for the Butler sabot (Plate XIV, Fig. 5). This is made of steel and in two parts; the one screwed upon the other when not in use. The lower part gauges the sabot as regards pitch and length of thread, length and thickness of ring; the upper part gauges the length and pitch of the thread upon the base of the shot.

A *small templet* (Plate XIV, Fig. 6), gauges the depth and width of cannelure and thickness of outer lip.

10. One *hammer*, weighing half a pound, having a flat face and conical point.

11. One *searcher* of steel wire No. 20 with handle; *steel punches* and a *cold-chisel*.

The shot should be inspected before it becomes rusty. It is first placed upon the rolling-table and examined with the eye for defects in material, which, in shot cast with the head down, are apt to occur as cavities in and about the base. These, when discovered, are probed with the "searcher" or steel punch; if more than 0″.2 deep, or of such character as to suggest weak, imperfect metal, the shot is condemned.

The head of the shot is struck with the hammer at its junction with the cylindrical part, for the purpose of detecting cracks liable to be produced there in cooling chilled shot. A dull sound indicates the existence of such a defect, which is further tested by hammering with a sledge. It is then rolled and, should the amount of eccentricity be considered doubtful as regards that allowed, is measured with the calipers.

The length of cavity and of screw-plug hole are then verified, and the templet applied to the profile. Rolling it from the table, it is stood on end and the gauge screwed to the base.

The sabot is then screwed to its gauge, the dimensions of the cannelure verified with the small templet, and the character of the metal examined. The sabot and screw-plug are then fitted to the shot, and it is again stood on its head and the ring-gauges are applied to it. The smaller should not pass over the shot at all; the larger should pass over its entire length.

It is then passed through the cylinder-gauge, which is fastened, slightly inclined, to a block of wood; the weight is finally determined and stamped at once upon the body of the shot near the sabot.

Shot and shell rejected during inspection are marked with an X made with a cold-chisel.

With each lot of shot, and from the same metal, is cast a cylindrical column about 2 feet high and 2½ inches in diameter in a sand mold, and the head of a projectile in the usual iron mold.

As soon as cool and before the shot have been sent to the "finishing shop," a test specimen is cut from the column, its specific gravity determined, then broken in the testing-machine, and its fracture examined. The chilled head is split under a hammer to expose the depth of chill, and the results so determined are compared with an occasional shot cut open along its axis. Should the tenacity, density, or chill be unsatisfactory the entire lot is condemned.

Chilled shot are intended for the penetration of wrought-iron plates, and were the result of experiments to substitute for the steel projectiles first used, one of cheaper material of the requisite hardness.

A fracture of the head of a chilled shot presents the following appearance:

The exterior layer is white, of crystalline structure, the crystals being disposed normal to the exterior surface. The central part is dark, granular, and less compact than the rest of the mass, showing the presence of considerable graphitic carbon, while the intermediate layers show less graphite and grow harder and denser as they approach and finally blend with the exterior.

Different metallurgic processes, and among them the repeated fusion of iron, qualify it for chilling.*

In consequence of the chilling process, the head is so hard as to resist even a file, while the cylindrical body is soft mottled iron. The head is not touched after casting in order to preserve intact the skin, which is the soundest and densest part.

The chilling power of the metal-mold, which depends upon its heat-conducting power, varies with its thickness and somewhat with its own temperature and that of the melted metal when poured into it.

The specific gravity of chilled cast iron is greater than that of gray or mottled iron, and this fact is used in discovering the depth of chill of a shot by weighing the shot first in air and then in water, and comparing the results with those obtained from a standard projectile of the same weight in air. The shot which weighs the less in water will be chilled to the less extent, since the discrepancy must be due to the lower density of its chilled head.

VI.—AMMUNITION FOR HOTCHKISS REVOLVING CANNON.

(Plate IV^{bis}.)

The ammunition for the revolving cannon consists of a wrapped metal center-fire metallic cartridge of special construction, containing the powder, projectile, the lubricating wad and primer.

Two kinds of projectiles are used—an explosive shell and a case-shot. The latter does not differ from the common case or canister shot used in ordinary cannon.

The shell—Plate IV^{bis}.

The shell is of novel construction, is made of cast iron, of a cylindro-ogival form, slightly rounded at the rear end. A brass band, about one caliber in length, envelopes the central part of the body of the shell. This band is a piece of soft brass tubing, contracted with pressure over the body of the projectile. The latter has two grooves encircling it at the top and bottom ends. The band is forced into these grooves by the action of the powder-gas; the corresponding ribs take the rifling; turning of the band on the projectile is prevented by slight longitudinal cuts with a cold-chisel and friction of the expanded band.

The band of the projectile is conical in front, corresponding with the cone in the chamber of the gun, exactly centering in the bore as the forward movement commences. Its rear end is cylindrical for one-third of its length.

The shell is turned smooth, and is (0.4^{mm} 0$''$.016 nearly) in diameter less than the bore of the barrel. This projectile is made with great care and exactness, with only a very small deviation in dimensions.

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*The desired result has been obtained in England by adding to a mixture of gray iron and shot scrap four per cent. of ilmenite, an ore of iron in combination with titanic acid, and containing—

Iron oxide (equivalent to 45.3 metallic iron)	61.4
Titanic acid	33.2
Silica	4.2
Tin oxide	1.2
Manganese	Trace.

The fuse.—Plate IV^{bis}.

The fuse employed is the Hotchkiss percussion. It consists of a gun-metal body, closed at the front end with a nose-screw, forming the ogival point of the projectile; it has a conical hole at the rear, which is closed with a lead plug (the safety-plug), pressed in very tightly, so that the plug projects a little through the base of the body-case towards the inside.

The plunger is composed of lead cast into a brass casing to strengthen it, and to prevent the lead being upset by the shock of discharge. Brass wires are cast into the lead of the plunger and hold it suspended in the case, the wires going through the slots in the bottom of the case and being held securely in position by the safety-plug. The plunger is recessed in front to receive a box-primer secured in place by pressing the lead of the plunger around it, and protected from premature explosion by a lozenge-shaped piece of thin brass bent over and forced into the lead.

The operation of the fuse is thus:

The safety-plug is dislodged backwards into the interior of the projectile by the shock of discharge; the wires being freed, the plunger is disengaged and rests on the bottom of the fuse-case, free to move in the line of axis. When the flight of the projectile is suddenly retarded the plunger, in consequence of its inertia, is driven forward, and the primer strikes against the point of the nose screw, thus igniting the powder in the channel.

The Hotchkiss percussion-fuse is extremely simple in construction, requiring no adjustment before use. It is perfectly safe in transportation and handling, the plunger being held securely by the safety-plug.

The cartridge-case.—Plate IV^{bis}.

The cartridge-case consists of a spirally-rolled tube of sheet-brass, strengthened at the head with an inside and an outside cup. The head is punched out of sheet-iron, and is fastened to the cups with three rivets.

The primer consists of a small case, in the pocket of which is the anvil and cup containing the fulminate; it is fitted into a hole through the head and both cups, and projects on the inside of the cartridge-case.

This cartridge can be manufactured with great facility on account of its simplicity; has proved to be very durable in quality, and it can be used as a reloader.

The construction of the body of the cartridge allows it to expand to the chamber of the gun without the metal being stretched. After the discharge it contracts and extracts freely.

The lubricator.

The lubricator consists of a wad of felt 6^{mm} (about $0''.236$) thick, dipped in a solution of tallow and beeswax. A paper disk between the lubricating-wad and the charge prevents the powder from contact with the lubricator.

The projectile is merely pressed into the neck of the cartridge, the friction holding it secure. The ammunition is safe from the influences of weather and accidental explosion.

Principal dimensions and weights of the ammunition.

EXPLOSIVE SHELL.

Length of body	inches	4.10
Entire length, with fuse	do	4.71
Length of brass coating, equidistant from center of gravity	do	1.5
Diameter of body	do	1.44
Diameter of brass coating	do	1.49
Weight of body of the projectile	lb. ozs	1 1.4
Weight of fuse	ozs	3.3
* Weight of bursting-charge	do	0.88
Total weight of projectile complete for firing	lb. ozs	1 5.58

CASE-SHOT.

Length of case	inches	4.565
Exterior diameter of case	do	1.440
Number of balls		.....
Diameter of each ball	inch	0.62
Average weight of each ball	ozs	1.03
Total weight of shot	lb. ozs	1 9.4

CARTRIDGE-CASE.

Length of cartridge-case	inches	4.724
Diameter of head	do	1.791
Diameter of body near the head	do	1.641
Diameter of body in front	do	1.476
Weight of cartridge-case	ozs	3.88

CHARGE OF POWDER.

Charge	ozs	4.23
Proportion of charge to weight of projectile	do	4.33
Weight of complete cartridge	lb. ozs	1 10.46
Length of complete cartridge	inches	8.149

Ammunition for Hotchkiss mountain gun.

Is similar to that for the revolving cannon (Plate IV^{bis}), except in dimensions and formation of the head of the cartridge-case. A vent in the wrought-iron head admits the flame of a friction-primer to the charge through the holes in the inner perforated disk, the outer vent being closed by the action of the gas on the disk.

Principal weights and dimensions.

EXPLOSIVE SHELL.

Entire length, with fuse	inches	5.7
Length of brass coating	do	1.8
Diameter of body	do	1.64
Diameter of brass coating	do	1.68
Weight of empty shell	pounds	1.65
Weight of percussion-fuse	do	.22
Weight of bursting-charge	do	.11
Weight of projectile—total	do	1.98

CARTRIDGE-CASE.

Length of cartridge-case	inches	6
Diameter of head	do	2
Diameter of body at head	do	1.83

* It may be advisable to use gun-cotton or picrate-powder for the bursting-charge, to throw the fragments with more force than ordinary gunpowder, and produce greater destructive effect.

Diameter of body at point	do...	1.64
Whole length of cartridge	do...	10.4
Weight of cartridge-case	pound..	.341
Weight of charge	do...	.363
Weight of cartridge and shell, complete	pounds..	2.684

VII.—AMMUNITION FOR GATLING GUNS.

The ammunition for the small Gatling guns, caliber .45, is the service small-arm ammunition. The .50 caliber Gatling guns use also small-arm ammunition of that size.

For the 1-inch Gatling gun, metallic-case cartridges of similar construction are used with a solid elongated projectile, weighing half a pound. A long case, containing 15 buckshot in groups of three, and a hemispherical projectile, is also used with these guns.

VIII.—APPENDIX.

To find the weight of a cast-iron shot or shell: Multiply the cube of the diameter of the shot in inches by .13268, and the difference of the cubes of the exterior and interior diameters of the shell by 0.13458, for the weight in pounds.

For lead balls, the multiplier is 0.2142 for a density of 11.301.

To find the diameter of a cast-iron shot of a given weight: Divide the weight in pounds by 0.134, and the cube root of the quotient will be the diameter in inches.

To find the quantity of powder which a shell will contain: Multiply the cube of the interior diameter of the shell in inches by 0.01744 for the weight of powder in pounds.

Preservation and piling of balls.

Balls should be carefully lacquered as soon as possible after they are received. All spherical case-shot are painted red. Other projectiles are lacquered *black*. For the composition of lacquer and the manner of applying it, see Ord. Mem. 23.

When it becomes necessary to renew the lacquer, the old lacquer should be removed by rolling or scraping the balls, which should never be heated for that purpose.

Balls are piled according to kind and caliber, under cover if practicable, in a place where there is a free circulation of air, to facilitate which the piles should be made narrow if the locality permits; the width of the bottom tier may be from 12 to 14 balls, according to the caliber.

Prepare the ground for the base of the pile by raising it above the surrounding ground so as to throw off the water; level it, ram it well, and cover it with a layer of screened sand. Make the bottom of the pile with a tier of unserviceable balls buried about two-thirds of their diameter in the sand; this base may be made permanent: clean the base well and form the pile, putting the fuse-holes of shells downwards, in the intervals, and not resting on the shells below. Each pile is marked with the number of serviceable balls it contains.

The base may be made of bricks, concrete, stone, or with borders and braces of iron. Good and imperfect balls should not be used in the same base; and, to avoid confusion, the unserviceable should be left unpainted, or painted of a different color from the serviceable.

Grape and canister shot should be oiled or lacquered, put in piles, or in strong boxes, on the ground floor, or in dry cellars, each parcel marked with its kind, caliber, and number.

To find the number of balls in a pile: Multiply the sum of the three parallel edges by one-third of the number of balls in a triangular face.

In a square pile one of the parallel edges contains but one ball; in a triangular pile two of the edges have but one ball in each.

The number of balls in a triangular face is $\frac{n(n+1)}{2}$; n being the number in the bottom row.

The sum of the three parallel edges in a triangular pile is $n + 2$; in a square pile, $2n + 1$; in an oblong pile, $3N + 2n - 2$, N being the length of the top row, and n the width of the bottom tier; or $3m - n + 1$, m being the length and n the width of the bottom tier.

If a pile consists of two piles joined at a right angle, calculate the contents of one as a common oblong pile, and of the other as a pile of which the three parallel edges are equal.

To find the length of a pile which shall hold a given number of balls, the width of the base being fixed:

A = the number of balls to be piled.

n = the number in the width of the base of the pile.

m = the number of balls in the length of the base of the pile; then

$$m = \frac{6A + n(n+1)(n+1)}{3n(n+1)}$$

In the following table of the number of balls in a pile, the second line shows the number in a triangular pile, the base of which is the corresponding number in the first line.

The other numbers show the contents of square and oblong piles; the length and width of the base being in the upper line and in the left-hand column, respectively.

For rifle projectiles: Divide the number of projectiles to be piled by the number in the triangular face decided upon, and multiply this number by the caliber in feet of the particular projectile to be piled.

RIFLE PROJECTILES.

The dimensions provisionally adopted for service rifle projectiles are as follows, viz:

Total length, $2\frac{1}{2}$ calibers.

Radius of head, $1\frac{1}{2}$ diameter of projectile.

Windage, $0''.05$.

The cavity for cored shot and for shells is of a somewhat similar form to the exterior of the projectile, except that the bottom is rounded, and its size is so proportioned as to secure the proper weight to the projectile.

The following formulas are useful in connection with this subject:

Volumes of solid ogival heads.

For an ogival head of 1 diameter radius:

$$\text{Volume of head} = D^3 \times 0''.395592.$$

For an ogival head of $1\frac{1}{4}$ diameter radius:

$$\text{Volume of head} = D^3 \times 0''.44765.$$

For an ogival head of $1\frac{1}{2}$ diameter radius:

$$\text{Volume of head} = D^3 \times 0''.49425.$$

(D = diameter of shot.)

Center of gravity of ogival head.

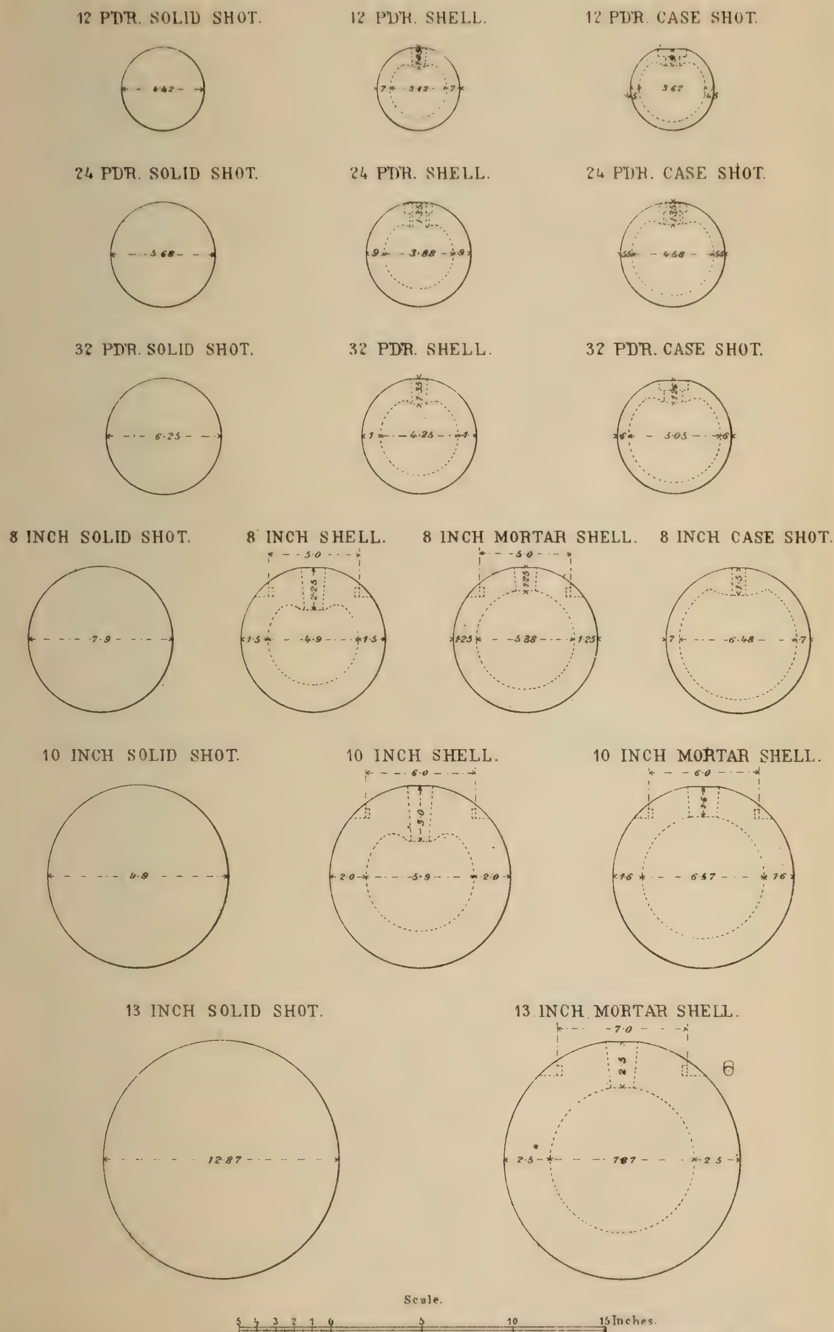
$$\text{Distance from base} = \frac{\frac{1}{2}(r^2 + a^2)\,g^2 - \frac{1}{4}\,g^4 + a\,(\frac{2}{3}\,a^3 - r^2)}{(r^2 + a^2)\,g - \frac{1}{3}\,g^3 + 2\,a\,s}$$

Length of head $= g$.
Radius of head $= r$.
Radius of head $-$ radius of projectile $= a$.

Weight of cored shot.

Small calibers $\frac{(\text{Diam.})^3}{3}$; large calibers $(\text{radius})^3 \times 2.8$.

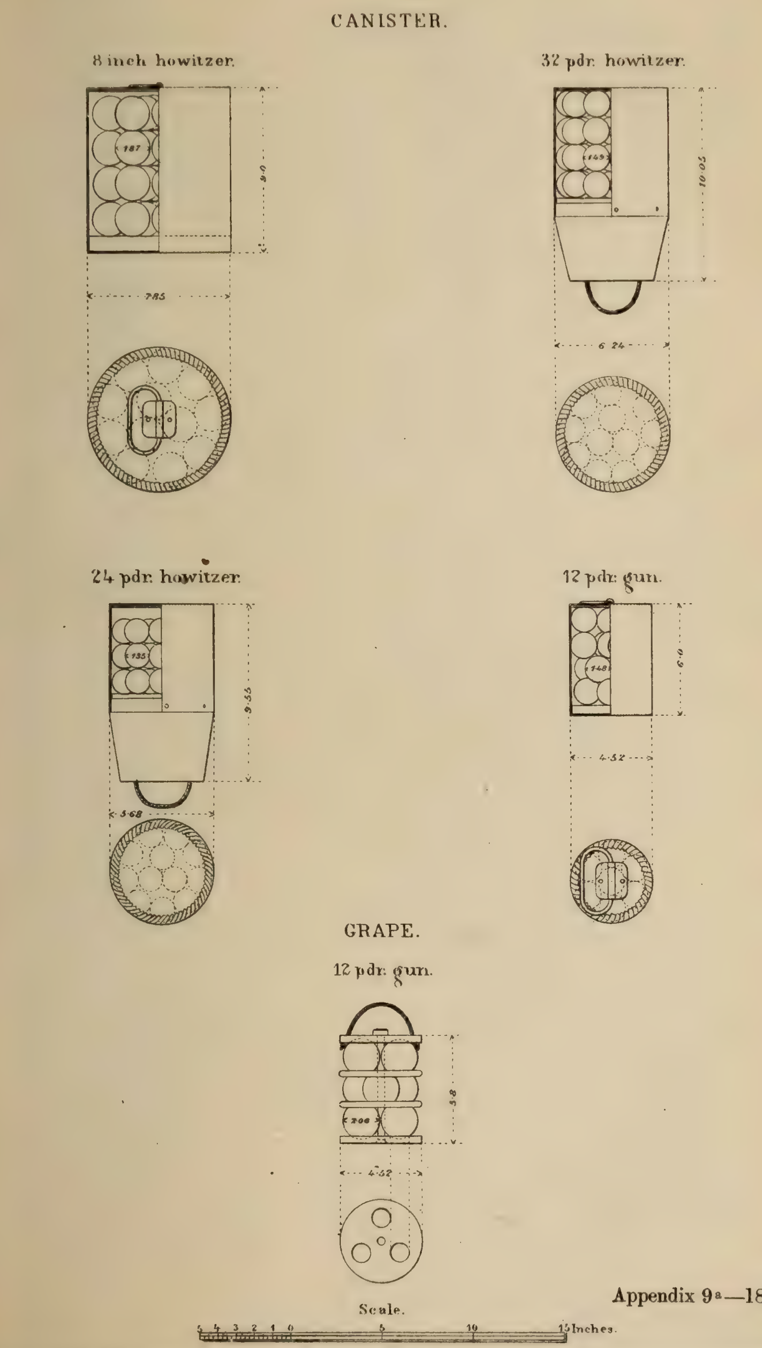
SPHERICAL PROJECTILES. U. S. LAND SERVICE.



Appendix 9ª—1880.

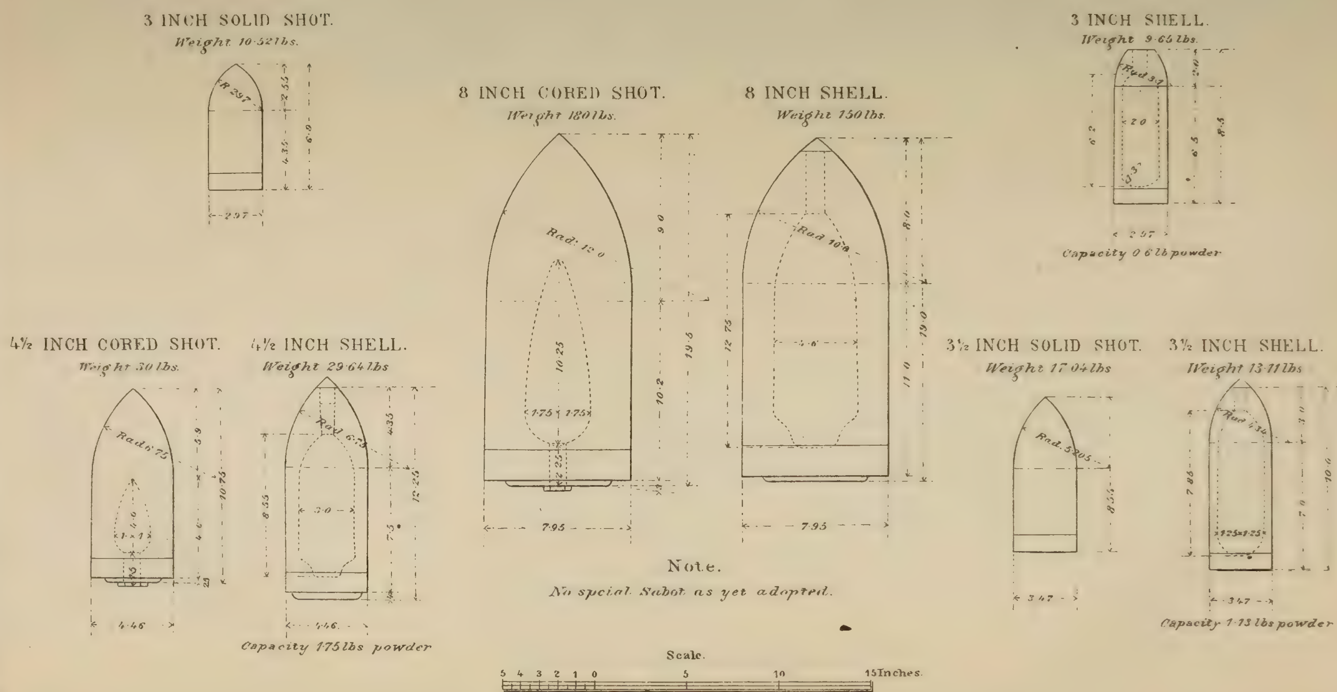
SPHERICAL PROJECTILES. U. S. LAND SERVICE.

S. B. CANISTER AND GRAPE SHOT. U. S. LAND SERVICE.

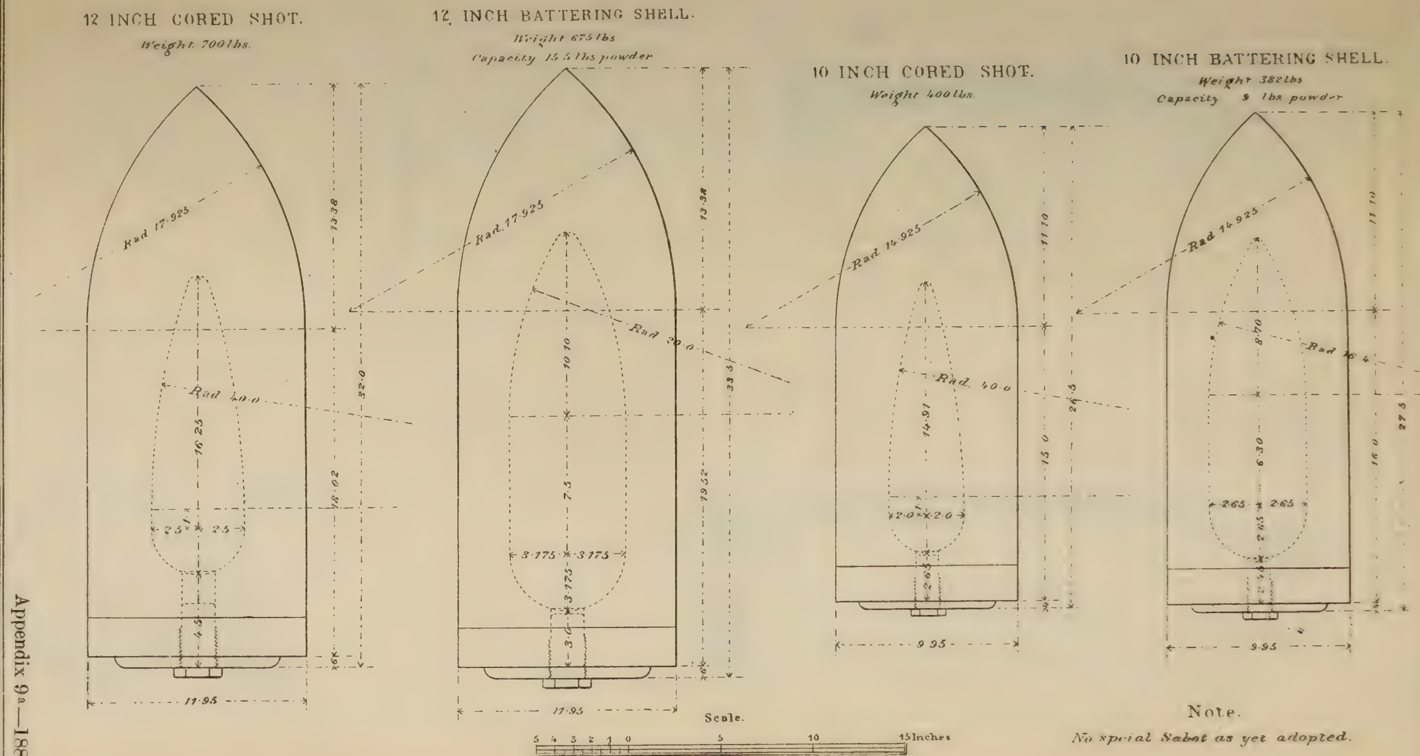


Appendix 9a—1880.

RIFLE PROJECTILES. STANDARD CALIBERS. U. S. LAND SERVICE.

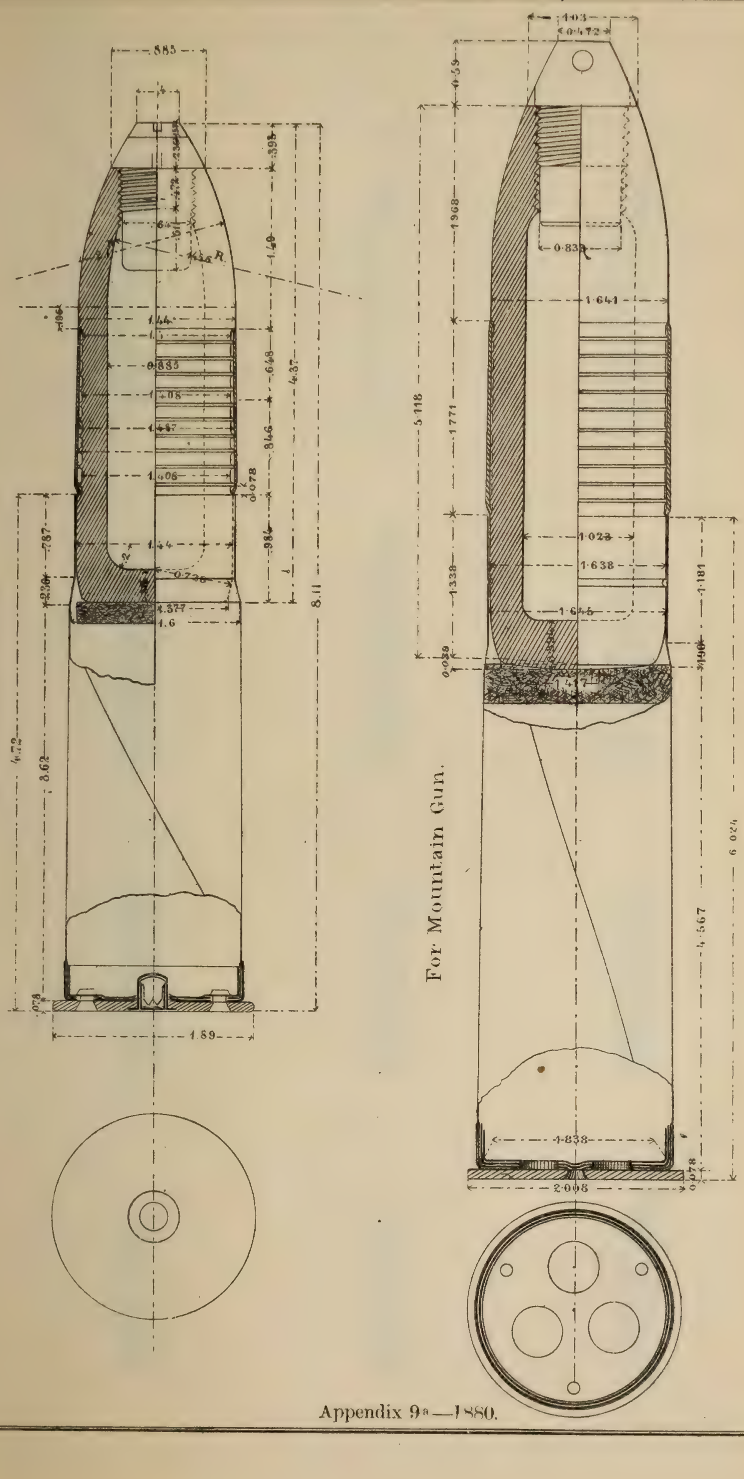


RIFLE PROJECTILES. STANDARD CALIBERS. U. S. LAND SERVICE.

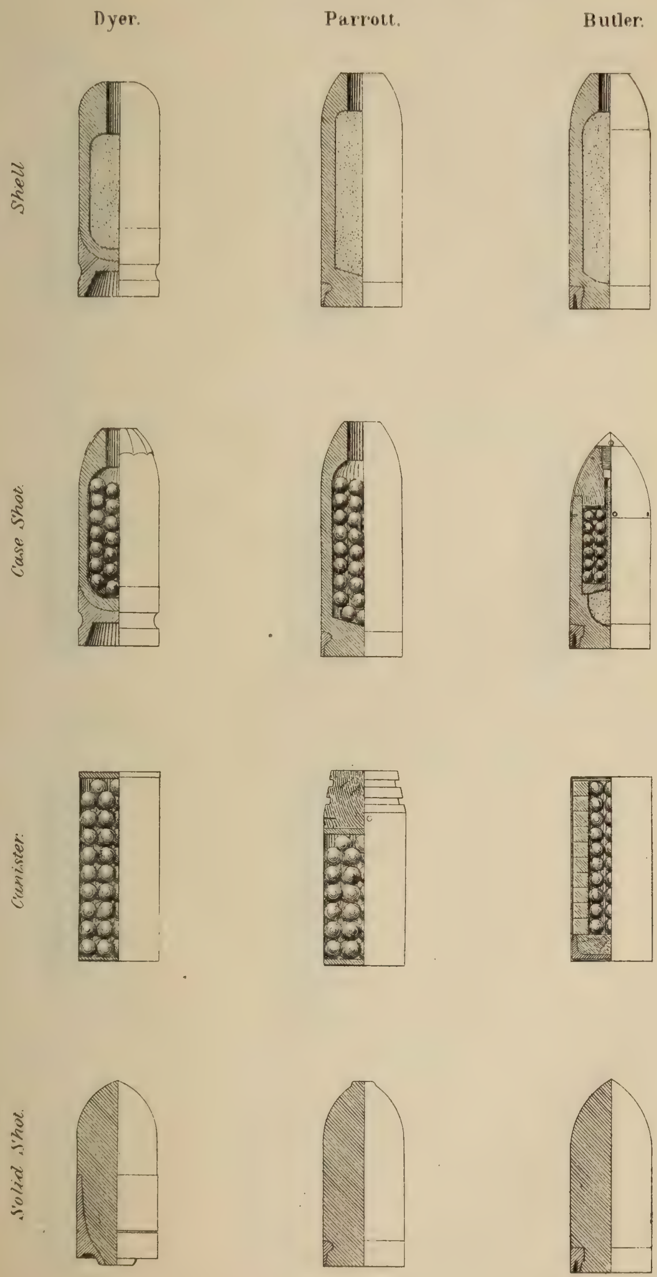


Note.
No special Sabot as yet adopted.

AMMUNITION FOR HOTCHKISS CANNON-REVOLVER AND MOUNTAIN GUN.

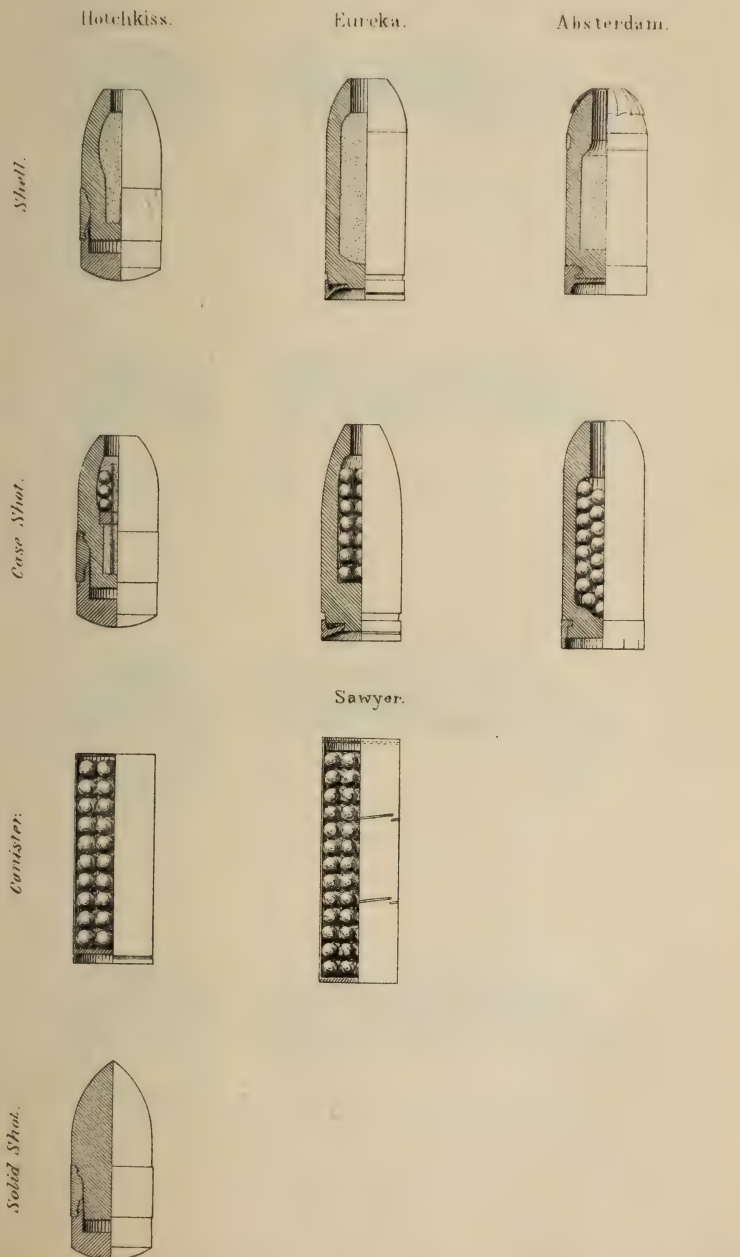


FIELD PROJECTILES, NOT ADOPTED AS STANDARD BUT SUBJECT TO ISSUE.



Appendix 9a—1880.

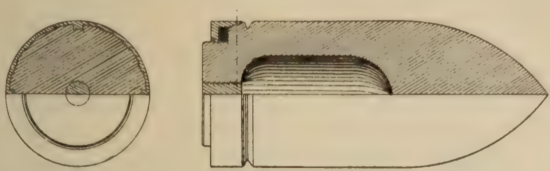
FIELD PROJECTILES, NOT ADOPTED AS STANDARD BUT SUBJECT TO ISSUE.



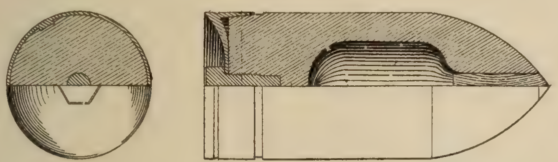
CORED SHOT LARGE CALIBERS.

NOT ADOPTED AS STANDARD BUT SUBJECT TO ISSUE.

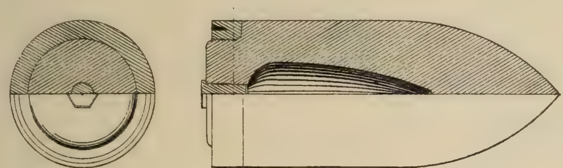
Dana.



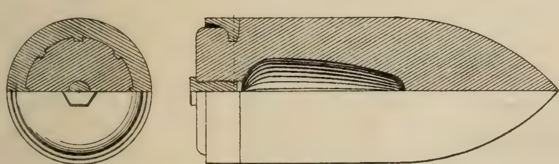
Arrick.

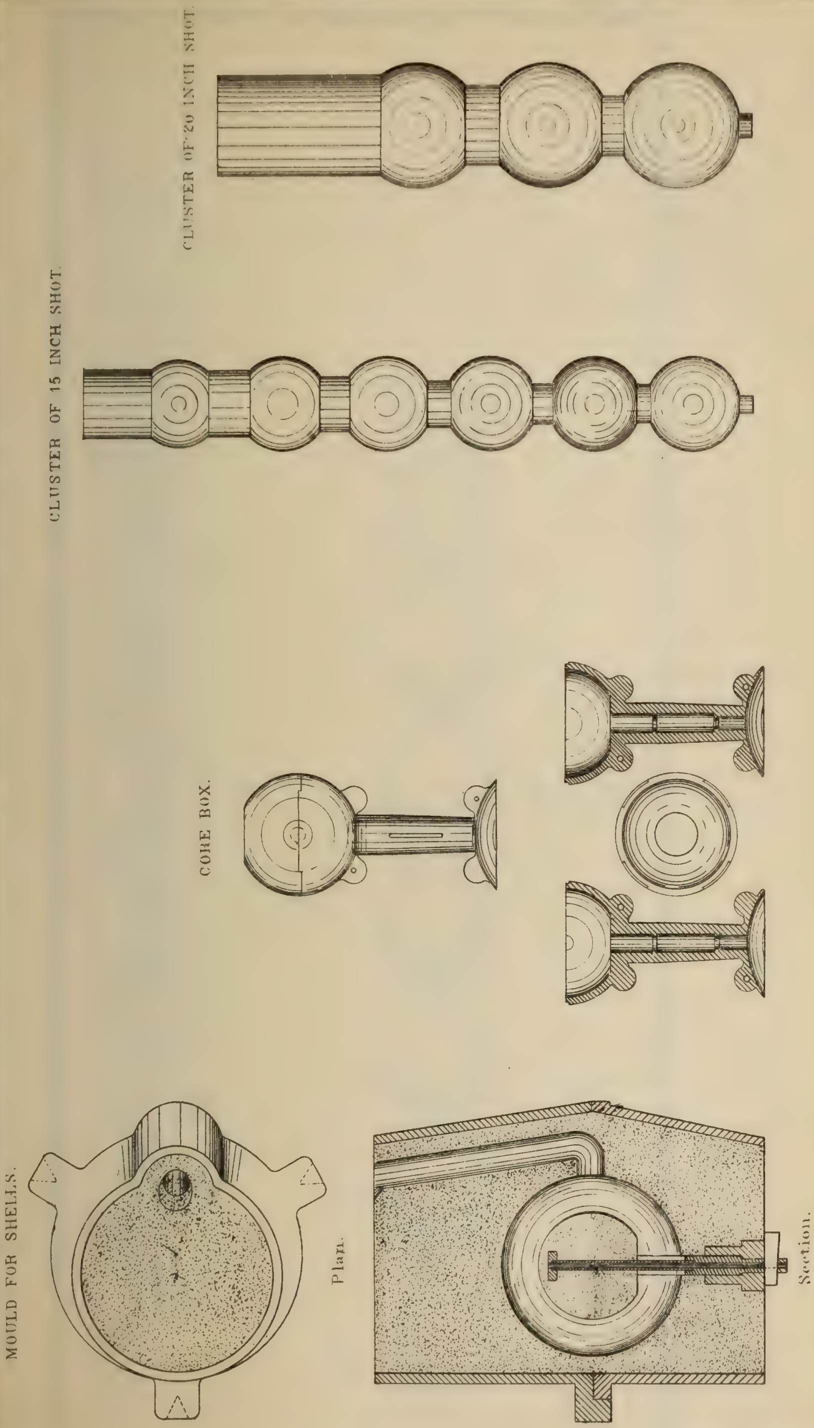


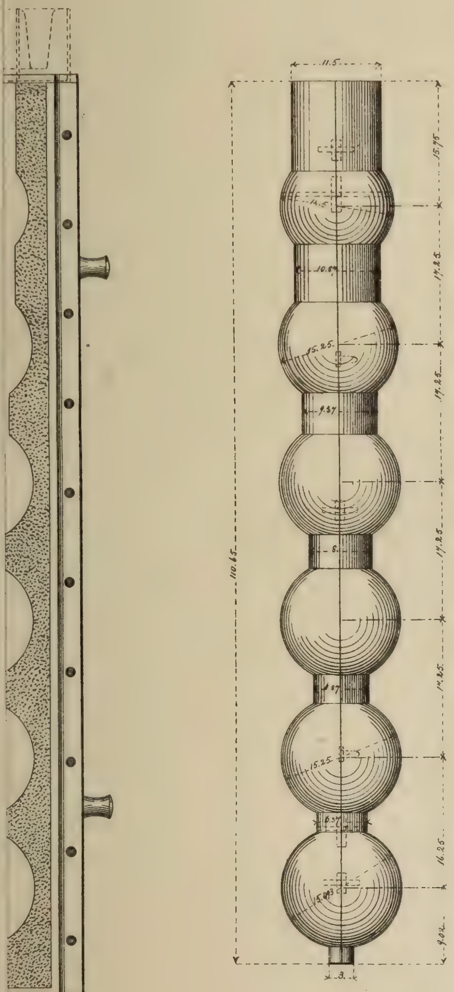
Butler.



Parrott.




CLUSTER OF 20 INCH SHOT.
CLUSTER OF 15 INCH SHOT.
CORE BOX.
MOULD FOR SHELLS.
Plan.
Section.

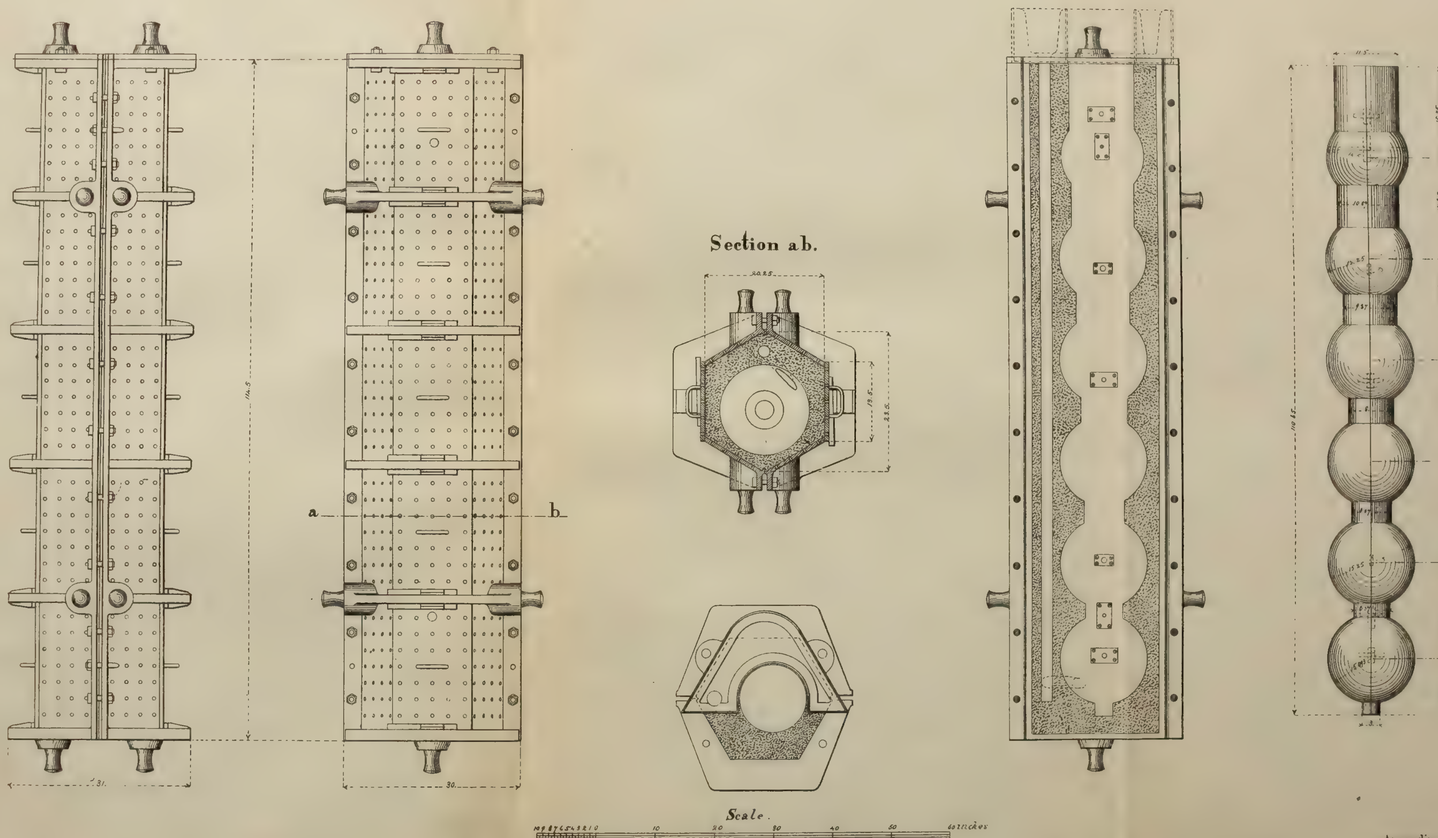


Appendix 9a—1880.

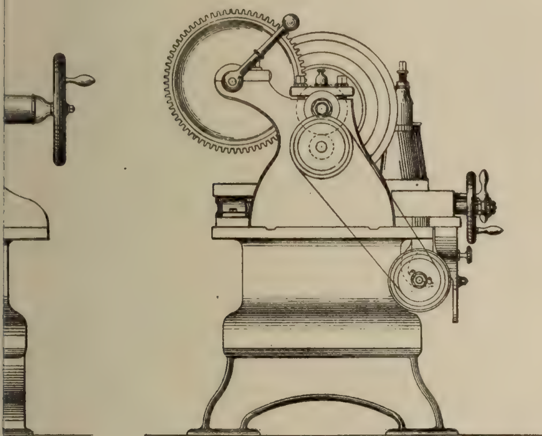
FLASK AND PATTERN.

for

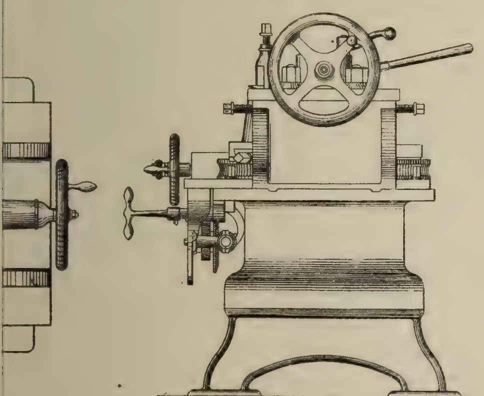
15 INCH CLUSTER SHOT.



Front Elevation.

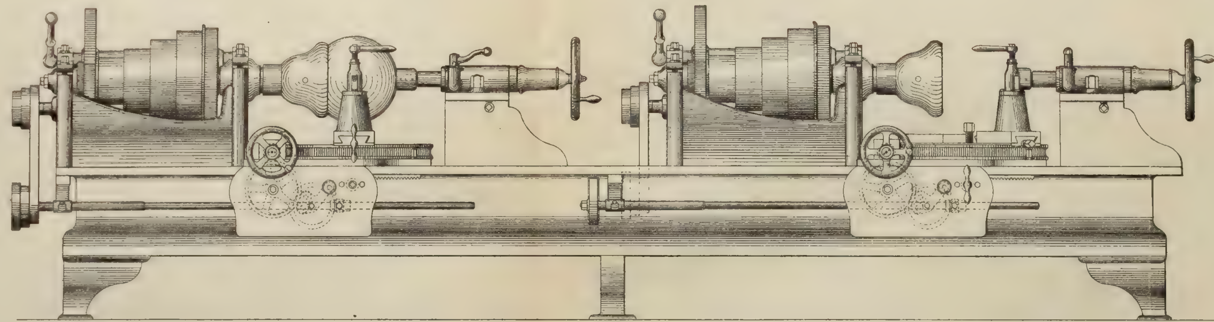


Rear Elevation.

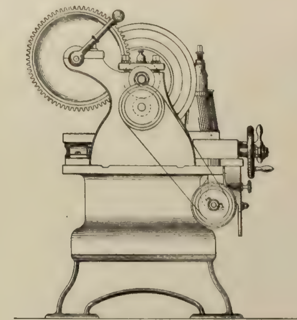


SHOT LATHE.

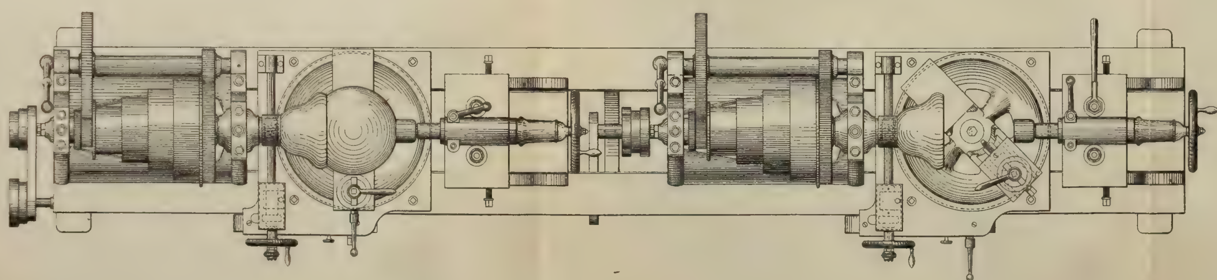
Side Elevation.



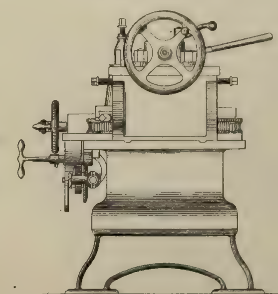
Front Elevation.



Plan.



Rear Elevation.



Scale

10 9 8 7 6 5 4 3 2 1 0 10 20 30 40 50 inches

CUPOLA FURNACE.

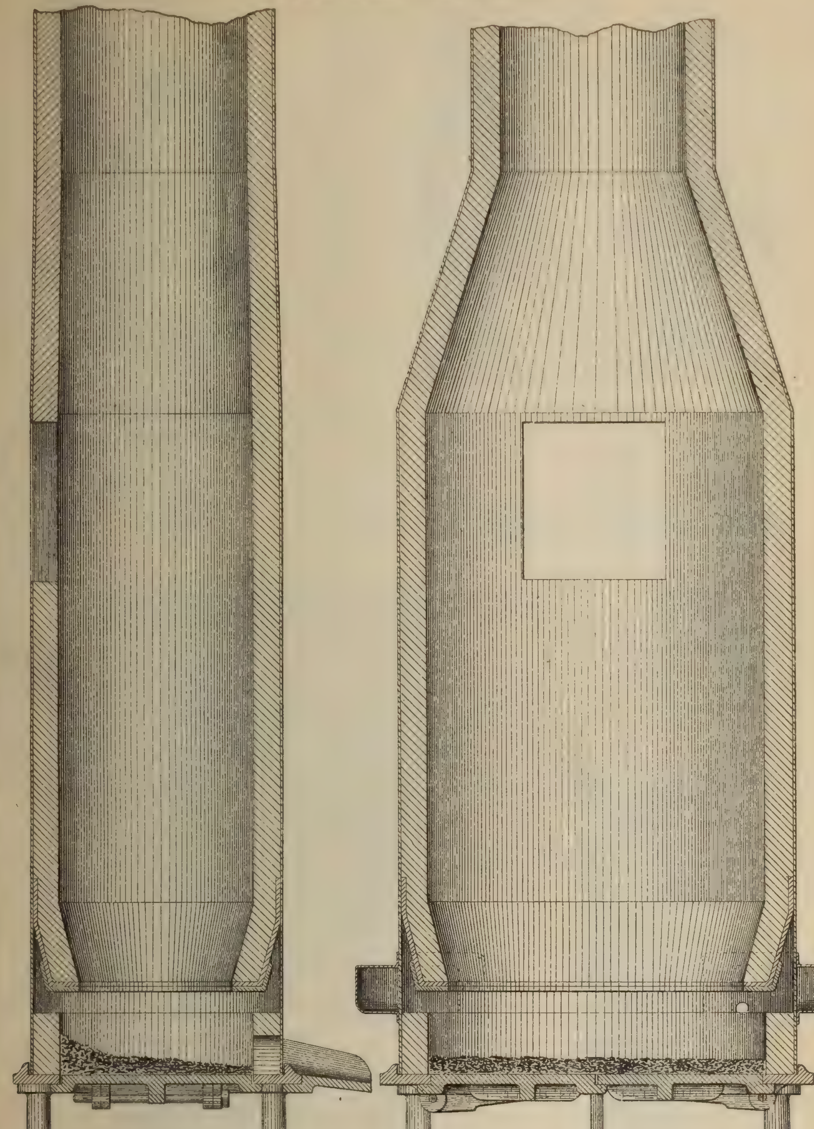
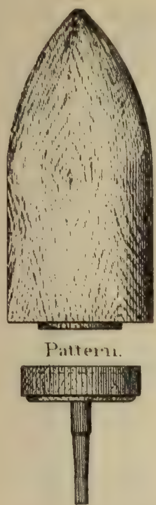


Fig. 1.



Pattern.

Fig. 2.

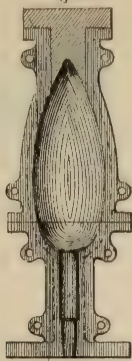
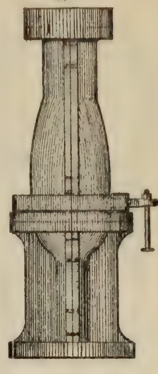


Fig. 3.



Core box.

Fig. 5.

Cross bar.

Fig. 6.

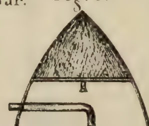
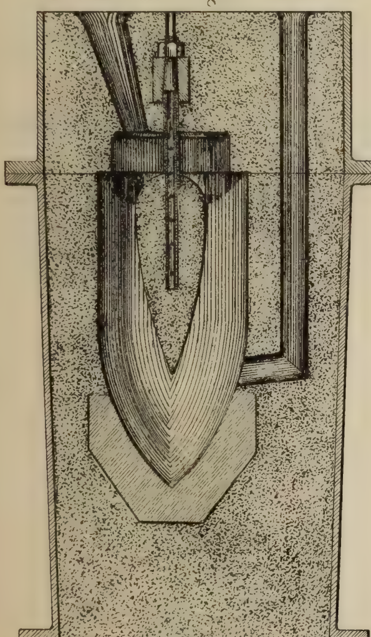
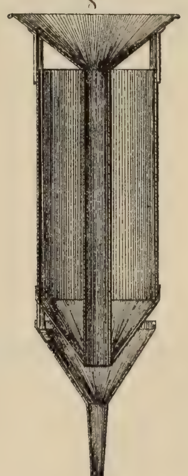


Fig. 4.



Section of Flask and Mould.

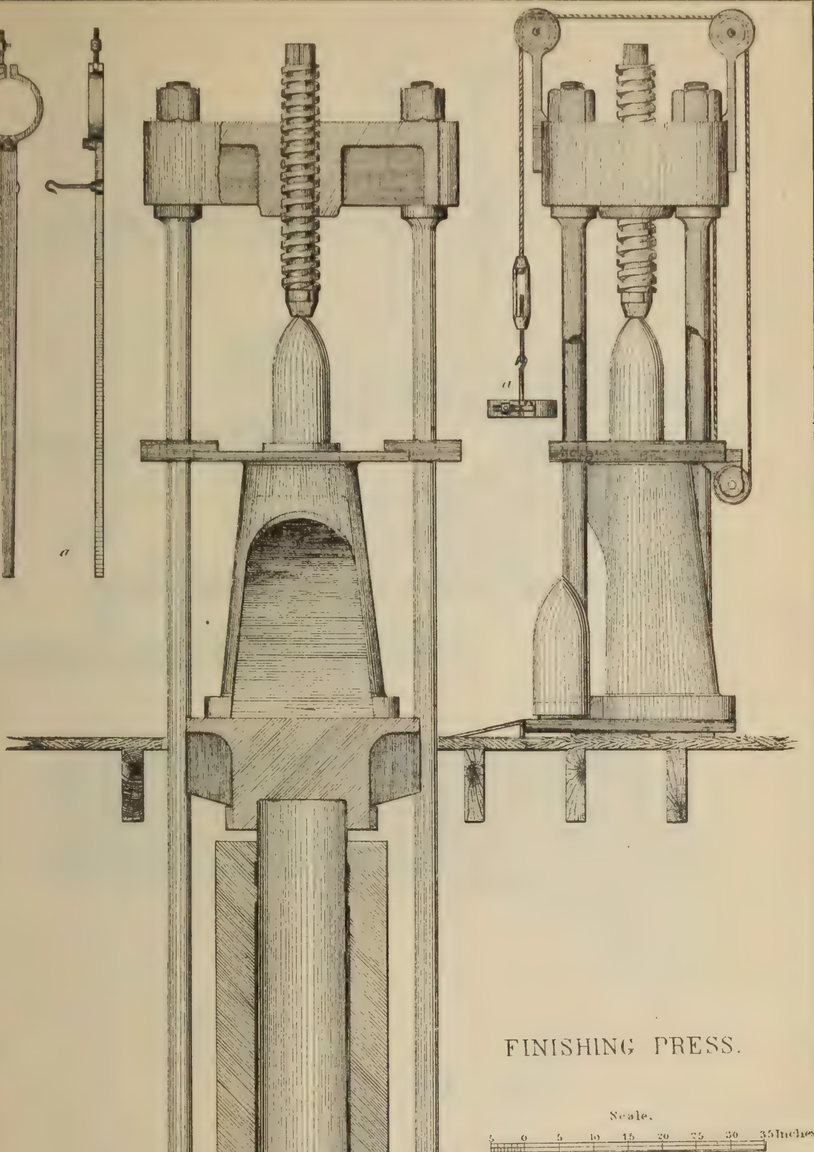
Fig. 7.



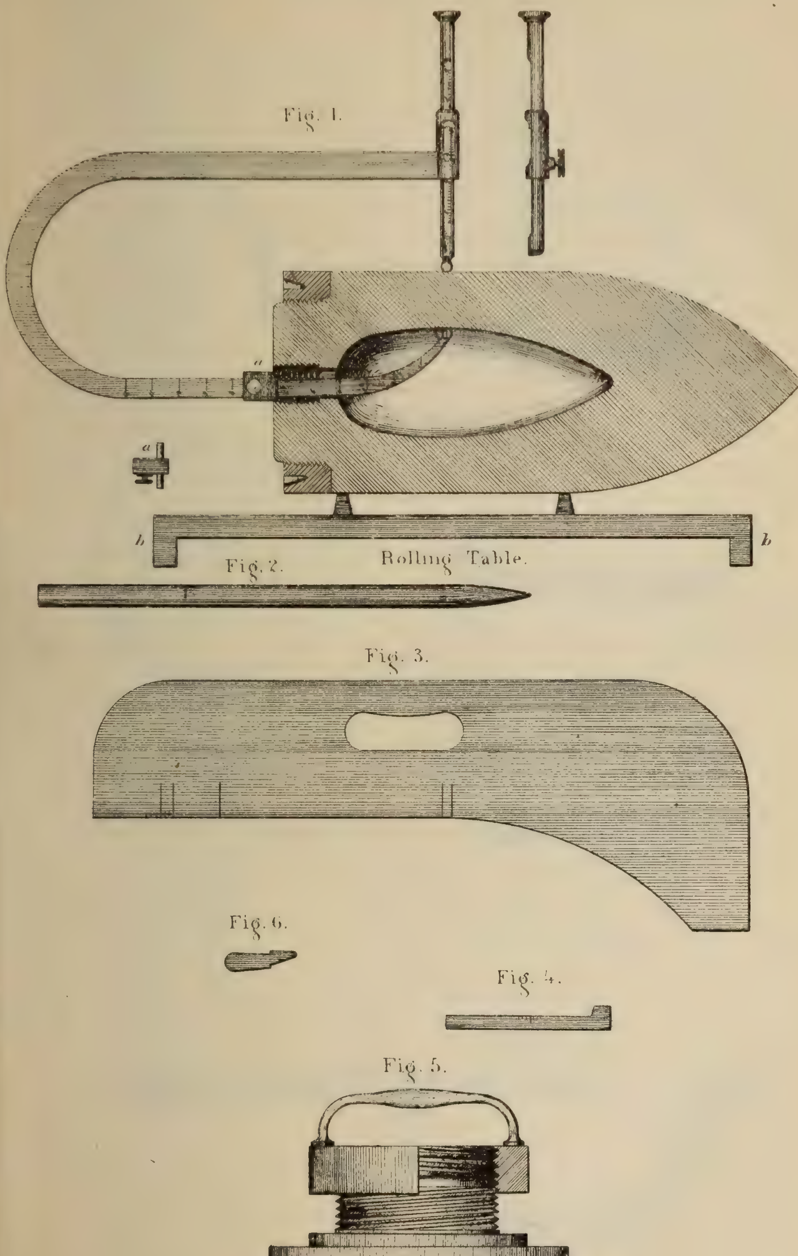
Funnel for coating mould with coke wash.

Scale.

1 0 5 10 15 Inches.



FINISHING PRESS.

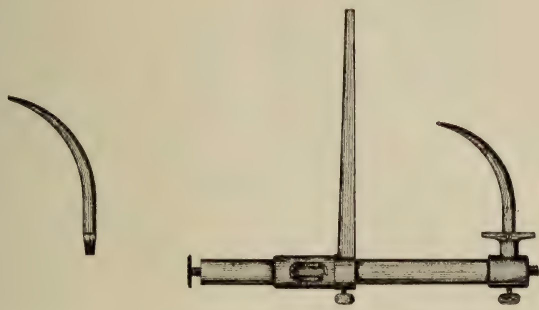


Gauges for sabot and base of shot.

Scale:

1 0 1 2 3 4 5 6 7 8 9 10 Inches.

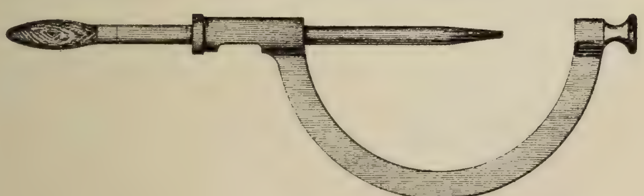
Appendix 9a—1880.



Calipers for side.

Fuze Gauge.

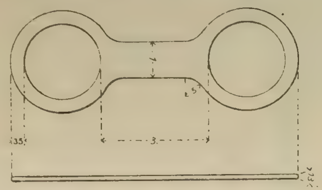
Calipers for bottom.



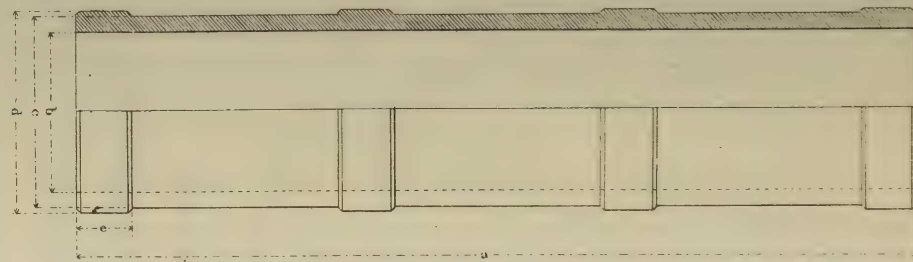
Scale.

Ring gauge.

For grape and canister shot.



Cylinder gauge.

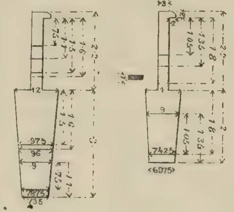


Canister shot gauges.

Diameter	24 pdr gun and 8 in. how.	12 pdr. gun and 32 pdr. how.	12 pdr how.
Large	1·87	1·49	1·08
Small	1·84	1·46	1·05

Fuze hole gauges.

For sph. case. For shells.

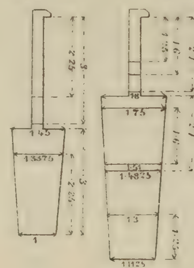


Dimensions of cylinder gauges.

	10 in.	8 in.	24 pdr.	12 pdr.
a	50.	40·	29	23
b	9·9	7·9	5·7	4·53
c	10·9	8·9	6·5	5·35
d	11·15	9·15	6·7	5·55
e	2·5	2·0	1·75	1·5

Fuze hole gauges.

Columbiad Mortar.



Grape shot gauges

Diameter	24 pdr.	12 pdr.
Large	2·64	2·06
Small	2·60	2·02

Table of the number of balls in a pile.

	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
Triangle	4	10	20	35	56	84	120	165	220	286	364	455	560	680	816	969	1,140	1,330	1,540	1,771
2	5																			
3	8	14																		
4	11	20	30																	
5	14	26	40	55																
6	17	32	50	70	91															
7	20	38	60	85	112	140														
8	23	44	70	100	133	168	204													
9	26	50	80	115	154	196	240	285												
10	29	56	90	130	175	224	276	330	385											
11	32	62	100	145	196	252	312	375	440	506										
12	35	68	110	160	217	280	348	420	495	572	650									
13	38	74	120	175	238	308	384	465	550	638	728	819								
14	41	80	130	190	259	336	420	510	605	704	806	910	1,015							
15	44	86	140	205	280	364	456	555	660	770	884	1,001	1,120	1,240						
16	47	92	150	220	301	392	492	600	715	836	962	1,092	1,225	1,360	1,496					
17	50	98	160	235	322	420	528	645	770	902	1,040	1,183	1,330	1,480	1,632	1,785				
18	53	104	170	250	343	448	564	690	825	968	1,118	1,274	1,435	1,600	1,768	1,938	2,109			
19	56	110	180	265	364	476	600	735	880	1,034	1,196	1,365	1,540	1,720	1,904	2,091	2,280	2,470		
20	59	116	190	280	385	504	636	780	935	1,100	1,274	1,456	1,645	1,840	2,040	2,244	2,451	2,660	2,870	
21	62	122	200	295	406	532	672	825	990	1,166	1,352	1,547	1,750	1,960	2,176	2,397	2,622	2,850	3,080	3.311
22	65	128	210	310	427	560	708	870	1,045	1,232	1,430	1,638	1,855	2,080	2,312	2,550	2,793	3,040	3,290	3,542
23	68	134	220	325	448	588	744	915	1,100	1,298	1,508	1,729	1,960	2,200	2,448	2,703	2,964	3,230	3,500	3,773
24	71	140	230	340	469	616	780	960	1,155	1,364	1,586	1,820	2,065	2,320	2,584	2,856	3,135	3,420	3,710	4,004
25	74	146	240	355	490	644	816	1,005	1,210	1,430	1,664	1,911	2,170	2,440	2,720	3,009	3,306	3,610	3,920	4,235
26	77	152	250	370	511	672	852	1,050	1,265	1,496	1,742	2,002	2,275	2,560	2,856	3,162	3,477	3,800	4,130	4,466
27	80	158	260	385	532	700	888	1,095	1,320	1,562	1,820	2,093	2,380	2,680	2,992	3,315	3,648	3,990	4,340	4,697
28	83	164	270	400	553	728	924	1,140	1,375	1,628	1,898	2,184	2,485	2,800	3,128	3,468	3,819	4,180	4,550	4,928
29	86	170	280	415	574	756	960	1,185	1,430	1,694	1,976	2,275	2,590	2,920	3,264	3,621	3,990	4,370	4,760	5,159
30	89	176	290	430	595	784	996	1,230	1,485	1,760	2,054	2,366	2,695	3,040	3,400	3,774	4,161	4,560	4,970	5,390
31	92	182	300	445	616	812	1,032	1,275	1,540	1,826	2,132	2,457	2,800	3,160	3,536	3,927	4,332	4,750	5,180	5,621
32	95	188	310	460	637	840	1,068	1,320	1,595	1,892	2,210	2,548	2,905	3,280	3,672	4,080	4,503	4,940	5,390	5,852
33	98	194	320	475	658	868	1,104	1,365	1,650	1,958	2,288	2,639	3,010	3,400	3,808	4,233	4,674	5,130	5,600	6,083
34	101	200	330	490	679	896	1,140	1,410	1,705	2,024	2,366	2,730	3,115	3,520	3,944	4,386	4,845	5,320	5,810	6,314
35	104	206	340	505	700	924	1,176	1,455	1,760	2,090	2,444	2,821	3,220	3,640	4,080	4,539	5,016	5,510	6,020	6,545
36	107	212	350	520	721	952	1,212	1,500	1,815	2,156	2,522	2,912	3,325	3,760	4,216	4,692	5,187	5,700	6,230	6,776
37	110	218	360	535	742	980	1,248	1,545	1,870	2,222	2,600	3,003	3,430	3,880	4,352	4,845	5,358	5,890	6,440	7,007
38	113	224	370	550	763	1,008	1,284	1,590	1,925	2,288	2,678	3,094	3,535	4,000	4,488	4,998	5,529	6,080	6,650	7,238
39	116	230	380	565	784	1,036	1,320	1,635	1,980	2,354	2,756	3,185	3,640	4,120	4,624	5,151	5,700	6,270	6,860	7,469
40	119	236	390	580	805	1,064	1,356	1,680	2,035	2,420	2,834	3,276	3,745	4,240	4,760	5,304	5,871	6,460	7,070	7,700

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APPENDIX 9 *b*.

REPORT ON THE TRIAL ON THE 11-INCH MUZZLE-LOADING RIFLE NO. 1.

A full description of this gun with details of fabrication and measurements will be found in the report of the Constructor of Ordnance for 1879 (see Report of the Chief of Ordnance, 1879, pages 61–65).

CARRIAGE.

The carriage used throughout the trial was the ordinary barbette, front pintle, 15-inch carriage arranged with pneumatic buffers (14-inch cylinders), and with the slight modification of the trunnion-beds incident to the diminished diameter of trunnions adopted for the purpose of correcting muzzle preponderance. The bolster formerly used was replaced by the device described in the report of the Constructor of Ordnance for 1878 (see Report of Chief of Ordnance, 1878, Appendix R 4) for use with the 8-inch breech-loading rifle, the dimensions and weights having been increased in suitable ratio for the larger caliber of gun.

POWDERS.

The endurance test of the gun was so conducted as to combine with it the trial of various powders selected for experimental test with the 10, 11, and 12 inch rifles, with a view to determining the most desirable form for this especial caliber and noting *en passant* such results as might lead to preliminary specifications for powders suitable for the still greater calibers contemplated in the future. In this way the test for endurance embraced the experimental test of thirteen varieties of powders, the results of which, so far as regards velocities and corresponding energies and pressures, are collated in the table accompanying this report. At the fifty-third round the variety F. P. C. was settled upon for the next hundred rounds, and while the result was in the main satisfactory, it was thought at its conclusion, the one hundred and fifty-second round, advisable to try a duplication of the I. H., a powder of slightly higher density and finer granulation, with a view of securing equal energies and lower pressures and a granulation more suitable for this caliber. The result, it will be seen, was satisfactory, and the test was concluded with this form, a duplicate of the I. H., and classed I. H. A.

PROJECTILES.

The projectiles used were elongated, cast-iron, cored shot with soft metal sabots of the Butler pattern, and of weights averaging originally 500 and 550 pounds. The diminution in weights, as shown in the table, is due to abrasion in passing into or through the sand-butts, the projectiles having been recovered and, after re-sabotting, re-employed.

EFFECTS ON THE GUN.

The trial of this gun was purely one of endurance, and, with charges as shown in the table, proceeded without event to the two hundred and

thirty-seventh round when, the impressions having shown unusual wear in the vent piece, it was removed for examination. Its lower portion was found to be badly eaten away for a distance of $2\frac{1}{4}$ inches from the bottom, and for $1\frac{3}{4}$ inches of this distance crushed together towards the center. In replacing it the vent aperture was increased one-fourth of an inch in diameter in consequence of the injury to the lower threads in the wrought-iron tube, and the new piece dimensioned accordingly. The test then proceeded without further incident to the three hundred and twenty-first round, when a slight weld defect was detected at the lower end of the tube directly in front of the wrought-iron cup closing the bottom of the bore. Carefully noting the effects, the firing was continued until the "tewtale" plainly pointed to an escape of gas between the tube and its surrounding jacket which, together with the gutta-percha impressions taken, evidently indicated a gradual development of the defective weld. At this stage, the conclusion of the three hundred and thirty-fifth round, it was decided to place in the bottom of the bore a bronze cup fitting mechanically the old cup, and with edges or lip projecting 3 inches beyond it, thus covering completely the defect mentioned. After this the gun was fired with full battering charges until the limit fixed upon, 400 rounds, was reached and passed. There was no further escape of gas, no abnormal enlargements of bore, and the gun, cupped as described, remained in serviceable condition.

EFFECTS ON THE CARRIAGE.

The carriage, as previously described, was used during the entire test of the gun, 401 rounds, without repair; it was easily manipulated, working smoothly and well, and gave complete satisfaction.

CONCLUSIONS.

The board regards the result of the trial as establishing the fact that reliable conversions of the 15-inch smooth-bores into 11-inch rifles can be made, and also that it affords additional evidence of the strength of this system of construction as applied to higher natures than the 8-inch conversions so successfully proved in former experiments. In view, however, of the fact of the successful proof of the 8-inch breech-loading rifle, involving in its construction the use of the wrought-iron tube for lining, and that breech-loading systems must supersede muzzle-loading, the board would recommend no further alterations to muzzle-loaders pending the manufacture and trial of a 11-inch breech-loader altered from a 15-inch smooth-bore now being fabricated at the South Boston foundry.

Table of enlargements of 11-*inch muzzle-loading rifle No.* 1.

Inches from muzzle.	Original play of tube, inches.	Original diameter of bore, inches.	Enlargements of bore, including "setting up" of tube, after— A total of 3 rounds.	A total of 4 rounds.	A total of 5 rounds.	A total of 39 rounds.	A total of 53 rounds.	A total of 75 rounds.	A total of 106 rounds.	A total of 142 rounds.	A total of 152 rounds.	A total of 179 rounds.	A total of 232 rounds.	A total of 248 rounds.	A total of 321 rounds.	A total of 333 rounds.	A total of 351 rounds.	A total of 391 rounds.	A total of 401 rounds.
141	0.006	11.007	0.033	0.033	0.034	0.034	0.040	0.040	0.041	0.048	0.048	....	0.050	0.050	0.054	0.055	0.055	0.057	0.057
140	.006	11.007	.033	.033	.035	.035	.040	.040	.041	.049	.049	.049	.050	.051	.054	.056	.056	.057	.057
139	.006	11.007	.033	.033	.034	.034	.041	.041	.042	.050	.050	.050	.050	.050	.055	.055	.055	.057	.057
138	.006	11.007	.033	.033	.033	.033	.040	.040	.041	.049	.049	.049	.050	.050	.054	.057	.057	.057	.057
137	.006	11.007	.032	.032	.032	.032	.040	.040	.040	.048	.049	.049	.050	.051	.057	.058	.058	.058	.058
136	.006	11.008	.030	.030	.030	.030	.037	.037	.038	.047	.048	.048	.049	.050	.054	.055	.055	.055	.055
135	.006	11.008	.028	.029	.029	.029	.036	.036	.037	.047	.048	.048	.048	.049	.055	.055	.055	.055	.055
134	.006	11.008	.027	.027	.027	.027	.035	.035	.036	.047	.047	....	.050	.052	.052	.059	.059	.059	.059
133	.006	11.008	.027	.027	.027	.027	.035	.035	.036	.046	.046	....	.050	.051	.056	.059	.059	.060	.060
132	.005	11.008	.027	.027	.027	.030	.036	.036	.038	.045	.045	....	.050	.052	.056	.059	.065	.065	.065
131	.005	11.009	.025	.025	.025	.028	.034	.034	.037	.041	.042	....	.048	.050	.051	.054	.055	.061	.062
130	.005	11.007	.024	.025	.025	.027	.034	.034	.038	.043	.043	.043	.049	.054	.058	.060	.060	.063	.066
129	.005	11.009	.021	.021	.021	.022	.029	.029	.036	.037	.037	....	.042	.046	.048	.051	.051	.056	.060
128	.005	11.008	.019	.020	.020	.023	.027	.027	.030	.036	.038	....	.040	.042	.045	.047	.047	.057	.062
127	.005	11.008	.019	.019	.019	.020	.022	.022	.035	.035	.035	....	.040	.042	.045	.045	.045	.056	.057
126	.005	11.007	.015	.015	.015	.017	.022	.021	.029	.029	.032	....	.037	.040	.042	.044	.046	.048	.053
125	.006	11.008	.010	.012	.012	.015	.017	.017	.026	.026	.026	.027	.031	.034	.041	.041	.041	.047	.050
124	.005	11.008	.010	.010	.010	.012	.015	.015	.022	.025	.026	....	.032	.033	.037	.039	.039	.052	.060
123	.005	11.008	.008	.008	.008	.010	.012	.013	.021	.022	.023	....	.030	.030	.032	.034	.040	.056	.058
122	.006	11.008	.006	.006	.006	.009	.010	.010	.018	.021	.021	....	.026	.026	.026	.030	.032	.047	.047
121	.006	11.008	.005	.005	.005	.007	.009	.009	.020	.020	.020	....	.022	.027	.027	.030	.030	.044	.044
120	.006	11.008	.003	.003	.003	.006	.007	.007	.015	.017	.017	.017	.020	.022	.022	.023	.027	.036	.038
119	.006	11.008	.002	.002	.002	.006	.006	.006	.014	.016	.016	....	.019	.022	.022	.022	.022	.033	.033
118	.005	11.008	.001	.001	.001	.005	.005	.005	.011	.014	.014	....	.015	.016	.018	.018	.020	.029	.030
117	.005	11.007	.001	.003	.003	.005	.005	.005	.010	.013	.013	....	.016	.017	.018	.019	.021	.028	.030
116	.005	11.007	.000	.000	.000	.003	.003	.003	.009	.011	.011	....	.014	.016	.017	.018	.018	.023	.026
115	.005	11.007	.000	.000	.000	.003	.003	.003	.008	.011	.011	.011	.012	.014	.016	.017	.017	.023	.026
114	.005	11.007	.000	.000	.000	.003	.003	.003	.008	.009	.009	....	.010	.012	.013	.015	.015	.021	.024
113	.006	11.007	.000	.000	.000	.003	.003	.003	.007	.009	.009	....	.011	.011	.013	.013	.014	.021	.021
112	.006	11.007	.000	.000	.000	.003	.003	.003	.007	.008	.008	....	.010	.011	.013	.013	.013	.018	.021
111	.006	11.007	.000	.000	.000	.001	.001	.001	.006	.008	.009	....	.009	.010	.012	.012	.012	.018	.021
110	.005	11.007	.000	.000	.000	.001	.001	.001	.006	.008	.009	.009	.009	.010	.012	.012	.012	.018	.021
109	.003	11.007	.000	.000	.000	.001	.001	.001	.005	.005	.005	....	.009	.010	.011	.012	.012	.018	.021
108	....	11.007	.000	.000	.000	.001	.001	.001	.005	.006	.006	....	.009	.009	.011	.012	.012	.018	.021
107	....	11.007	.000	.000	.000	.001	.001	.001	.004	.005	.005	....	.006	.008	.010	.010	.010	.013	.017
106	....	11.007	.000	.000	.000	.001	.001	.001	.002	.004	.004	....	.004	.007	.007	.008	.008	.011	.013
105	.008	11.007	.000	.000	.000	.001	.001	.001	.001	.004	.004	.004	.004	.004	.005	.006	.006	.008	.008

Table of enlargements of 11-*inch muzzle-loading rifle No.* 1—Continued.

Inches from muzzle.	Original play of tube, inches.	Original diameter of bore, inches.	Enlargements of bore, including "setting up" of tube, after— A total of 3 rounds.	A total of 4 rounds.	A total of 5 rounds.	A total of 39 rounds.	A total of 53 rounds.	A total of 75 rounds.	A total of 106 rounds.	A total of 142 rounds.	A total of 152 rounds.	A total of 179 rounds.	A total of 232 rounds.	A total of 248 rounds.	A total of 321 rounds.	A total of 333 rounds.	A total of 351 rounds.	A total of 391 rounds.	A total of 401 rounds.
104	.007	11.007	.000	.000	.000	.001	.001	.001	.001	.001	.002	....	.002	.003	.003	.003	.005	.006	.007
103	.008	11.007	.000	.000	.000	.000	.000	.000	.001	.002	.002	....	.002	.002	.002	.003	.003	.005	.006
102	.008	11.007	.000	.000	.000	.000	.000	.000	.001	.002	.002	....	.002	.002	.002	.003	.003	.005	.005
101	.012	11.007	.000	.000	.000	.000	.000	.000	.001	.002	.002	....	.002	.002	.002	.002	.002	.004	.005
100	.011	11.007	.000	.000	.000	.000	.000	.000	.001	.001	.001	.001	.001	.002	.002	.002	.002	.003	.004
99	.012	11.007	.000	.000	.000	.000	.000	.000	.001	.001	.001	....	.001	.001	.001	.001	.001	.003	.003
98	.011	11.007	.090	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.001	.002	.003
97	.011	11.007	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.001	.002
96	.011	11.007	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.001	.001
95	.011	11.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.002	.003
94	.002	11.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.002	.003
93	....	11.006	.000	.000	.000	.000	.000	.000	.001	.001	.001	....	.001	.001	.001	.001	.001	.002	.004
92	.003	11.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.001	.001	.001	.003	.004
91	....	11.010	.000	.000	.000	.000	.000	.000	.000	.002	.002	....	.002	.002	.002	.002	.003	.004	.005
90	.009	11.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.002	.002	.003	.004	.005
89	....	11.010	.000	.000	.000	.000	.000	.000	.000	.002	.002	....	.002	.002	.002	.002	.002	.004	.005
88	.009	11.010	.000	.000	.000	.000	.000	.000	.000	.002	.002	....	.002	.002	.002	.002	.002	.002	.004
87	....	11.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.002	.003
86	.002	11.010	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.001	.002
85	....	11.009	.000	.000	.000	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
84	.002	11.008	.000	.000	.000	.000	.000	.000	.001	.001	.001	....	.001	.001	.001	.001	.001	.002	.002
83	....	11.008	.000	.000	.000	.000	.000	.000	.001	.002	.002	....	.002	.002	.002	.002	.002	.002	.003
82	.005	11.008	.000	.000	.000	.000	.000	.000	.001	.002	.002	....	.002	.002	.002	.002	.002	.003	.003
81	....	11.008	.000	.000	.000	.000	.000	.000	.001	.002	.002	....	.002	.002	.002	.002	.002	.004	.004
80	.005	11.008	.000	.000	.000	.000	.000	.000	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.004
78	.007	11.008	.000	.000	.000	.000	.000	.000	.002	.002	.002	....	.002	.002	.002	.002	.002	.002	.002
76	.006	11.007	.000	.000	.000	.000	.000	.000	.003	.003	.003	....	.003	.003	.003	.003	.003	.003	.003
74	.006	11.007	.000	.000	.000	.000	.000	.000	.002	.002	.002	....	.002	.002	.003	.003	.003	.003	.003
72	.006	11.007	.000	.000	.000	.000	.000	.000	.002	.002	.002	....	.002	.002	.002	.003	.003	.003	.003
70	.007	11.007	.000	.000	.000	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.002	.002	.002	.002
68	.007	11.006	.000	.000	.000	.001	.001	.001	.001	.002	.002	....	.002	.002	.002	.003	.003	.003	.002
66	.005	11.006	.000	.000	.000	.001	.001	.001	.001	.002	.002	....	.002	.002	.002	.002	.002	.002	.002
64	.003	11.006	.000	.000	.000	.000	.000	.000	.000	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
62	.003	11.006	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
60	.002	11.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
58	.003	11.004	.000	.000	.000	.001	.001	.001	.001	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
56	.003	11.003	.000	.000	.000	.001	.001	.001	.001	.002	.002	....	.002	.002	.002	.002	.002	.002	.002
54	.004	11.003	.000	.000	.000	.001	.001	.001	.001	.001	.001	....	.001	.001	.001	.001	.001	.001	.002

52	.004	11.003	.000	.000	.000	.000	.001	.001	.001	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
50	.006	11.003	.000	.000	.000	.000	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
48	.008	11.003	.000	.000	.000	.000	.001	.001	.001	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
46	.007	11.003	.000	.000	.000	.000	.000	.000	.001	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
44	.005	11.003	.000	.000	.000	.000	.000	.000	.001	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
42	.005	11.003	.000	.000	.000	.000	.000	.000	.000	.001	.001	....	.001	.001	.001	.001	.001	.001	.001
40	.006	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001	.001	.001	.001
38	.007	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
36	.007	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
34	.007	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
32	.007	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
30	.007	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
28	.008	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
26	.002	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.001
24	.003	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
22	.004	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.001
20	.005	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.001
18	.005	11.003	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.001
16	.006	11.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
14	.005	11.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
12	.006	11.004	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
10	.007	11.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
8	.007	11.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
6	....	11.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
4	....	11.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
2	....	11.005	.000	.000	.000	.000	.000	.000	.000	.000	.000	....	.000	.000	.000	.000	.000	.000	.000
1	....	11.0[illegible]	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000

AVERAGES.

Record of firings for endurance with an experimental 11-inch muzzle-loading rifle, from August 1, 1879, to February 12, 1880, inclusive, at Sandy Hook, New Jersey.

DESCRIPTION OF GUN.—An 11-inch muzzle-loading rifle converted from a 15-inch Rodman cast-iron smooth-bore by lining with a jacketed wrought-iron coiled tube inserted from the rear or breech. Caliber, 11 inches. Total length of gun, 201.25 inches. Length of bore, 161.5 inches. Length of rifling, 141.5 inches. Diameter of bore, including grooves, 11.18 inches. Number of grooves and lands, 19. Twist uniform, one turn in 59.886 feet. Weight of gun, 54,730 pounds.

Date.	Number of shots.	Charge.				Projectile.			Mean observed velocities of the projectiles at 109 feet from the muzzle of the gun, as recorded by Le Boulangé chronograph.	Velocities at the muzzle.	Muzzle energy, foot-tons.			Gas pressure per square inch of bore as taken with Rodman's internal-pressure gauge.
		Kind of powder.	Cartridge.											
			Weight.	Height.	Diameter.	Kind.	Weight.	Diameter.			Total.	Per inch of shot's circumference.	Per pound of powder.	
			Lbs.	Inches.	Inches.		Lbs.	Inches.	Feet.	Feet.				Lbs.
August 1, 1879	2	Du Pont's hexagonal G. H.; density, 1.785; granulation, 67.	70	25. 50	10. 50	Butler	503	10. 94	1, 258	1, 262	5, 553	161. 57	79. 33	34. 250
August 1, and Nov. 4, 1879	7		75	26. 75	10. 50	..do ...	501	10. 94	1, 288	1, 292	5, 797	168. 67	77. 29	31, 500
August 8, 12, and 13, 1879	4	Du Pont's hexagonal H. R.; density, 1.780; granulation, 50.	70	25. 50	10. 50	..do ...	505	10. 94	1, 294	1, 299	5, 907	171. 87	84. 38	35, 000
Aug. 12, and Sept. 10, 1879	2	Du Pont's hexagonal H. S.; density, 1.800; granulation, 50.	70	25. 50	10. 50	..do ...	505	10. 94	1, 303	1, 308	5, 989	174. 26	85. 55	35, 250
Sept. 10, and Oct. 28, 1879	4		75	26. 75	10. 50	..do ...	503	10. 94	1, 337	1, 342	6, 280	182. 71	83. 73	33, 125
August 14, 1879	2	Du Pont's hexagonal F. P. B.; density, 1.785; granulation, 67.	70	25. 50	10. 50	..do ...	506	10. 94	1, 278	1, 283	5, 774	168. 00	82. 48	34, 500
October 29, 1879	8		75	26. 75	10. 50	..do ...	502	10. 94	1, 337	1, 343	6, 276	182. 62	83. 68	36, 438
August 14, 1879	2	Du Pont's square G. S.; density, 1.775; granulation, 11.	70	25. 50	10. 50	..do ...	504	10. 94	1, 213	1, 217	5, 175	150. 56	73. 93	24, 750
August 15, 1879	1		75	26. 75	10. 50	..do ...	506	10. 94	1, 216	1, 220	5, 221	151. 90	69. 61	25, 500
Do	1		80	28. 00	10. 50	..do ...	506	10. 94	1, 263	1, 268	5, 640	164. 09	70. 50	30, 000
Do	1		85	29. 25	10. 50	..do ...	506	10. 94	1, 235	1, 238	5, 376	156. 41	63. 24	24, 500
Do	1	Du Pont's square G. U.; density, 1.715; granulation, 11.	70	25. 50	10. 50	..do ...	506	10. 94	1, 256	1, 261	5, 578	162. 28	79. 68	33, 500
Do	2	42 pounds G. T. square; density, 1.760; granulation, 11; and 28 pounds H. R. hexagonal; density, 1.780; granulation, 50.	70	25. 50	10. 50	..do ...	506	10. 94	1, 267	1, 272	5, 675	165. 13	81. 67	34, 250
October 28, 1879	2	15 pounds G. T. square; density, 1.760; granulation, 11; and 60 pounds G. U. square; density, 1.715; granulation, 11.	75	26. 75	10. 50	..do ...	503	10. 94	1, 302	1, 307	5, 956	173. 3	79. 41	32, 000

October 29, 1879	1	30 pounds I. H. hexagonal; density, 1.800; granulation, 40; and 50 pounds H. S. hexagonal; density, 1.800; granulation, 50.	80	28.00	10.50	..do...	503	10.94	1.315	1,320	6,075	176.77	75.93	31,000
August 20 and 22, 1879	3	Du Pont's square G. T., density, 1.760; granulation, 11.	70	25.50	10.50	..do...	505	10.94	1,245	1,249	5,461	158.89	78.01	31,500
September 10, 1879	1		75	26.75	10.50	..do...	505	10.94	1,316	1,321	6,109	177.74	81.45	33,000
October 7, 1879	1	Du Pont's hexagonal I. G.; density, 1.770; granulation, 40.	70	25.50	10.50	..do...	504	10.94	1,320	1,325	6,134	178.47	87.63	37,500
Do	1	Du Pont's hexagonal I. H.; density, 1.800; granulation, 40.	70	25.50	10.50	..do...	506	10.94	1,237	1,241	5,402	157.17	77.17	23,500
Do	1		70	25.50	10.50	..do...	550	10.94	1,194	1,198	5,472	159.21	78.17	22,500
Do	1		75	26.75	10.50	..do...	550	10.94	1,232	1,236	5,825	169.47	77.66	25,000
Do	1		80	28.00	10.50	..do...	503	10.94	1,318	1,323	6,103	177.57	76.29	27,000
Do	1		80	28.00	10.50	..do...	552	10.94	1,253	1,257	6,046	175.91	75.57	27,000
Do	1		85	29.25	10.50	..do...	552	10.94	1,290	1,294	6,407	186.42	75.37	30,000
November 6, 1879	1	Hazard's cubical A. C.; density, 1.7654; granulation, 54.	50	20.50	10.50	..do...	500	10.94	....	....	....	....	....	28,000
August 6, 1879	1	Du Pont's hexagonal F. P. C.; density, 1.785; granulation, 67.	70	25.50	10.50	..do...	503	10.94	1,305	1,310	5,984	174.10	85.48	39,000
November 26, 1879	2		70	25.50	10.50	..do...	542	10.94	1,290	1,294	6,291	183.05	89.87	33,250
Oct. 29: Nov. 3 and 26; and Dec. 18, 1879; Jan. 2, 8, 9, and 20, 1880.	84		75	26.75	10.50	..do...	489	10.94	1,367	1,373	6,390	185.93	85.20	35,900
Nov. 26, and Dec. 3, 1879	11		75	26.75	10.50	..do...	542	10.94	1,306	1,311	6,458	187.89	86.10	34,500
November 13, 1879	1	Du Pont's hexagonal I. H. A.; density, 1.800; granulation, 40.	70	25.50	10.50	..do...	498	10.94	1,275	1,280	5,656	164.56	80.80	29,000
Do	1		70	25.50	10.50	..do...	548	10.94	1,226	1,229	5,738	166.95	81.97	27,500
February 11, 1880	2		75	26.75	10.50	..do...	549	10.94	1,252	1,256	6,004	174.68	80.05	32,500
November 13, 1879	1		80	28.00	10.50	..do...	497	10.94	1,316	1,321	6,012	174.92	75.15	31,500
Nov. 13, 1879, and Feb. 11, 1880	3		80	28.00	10.50	..do...	549	10.94	1,280	1,284	6,274	182.56	78.42	29,000
Nov. 13, 14, and 15, 1879	12		85	29.25	10.50	..do...	501	10.94	1,371	1,376	6,576	191.32	77.36	33,083
Nov. 14, 15, and 25, and Feb. 11, 1880.	27		85	29.25	10.50	..do...	548	10.94	1,314	1,319	6,609	192.30	77.75	31,375
Nov. 25 and 26; Dec. 18, 30, and 31, 1879; and Jan. 9, 10, 17, 20, and 21, and Feb. 11 and 12, 1880.	27		90	30.50	10.50	..do...	495	10,94	1,413	1,419	6,909	201.03	76.76	22,167
	174		90	30.50	10.50	..do...	543	10.94	1,347	1,352	6,880	200.19	76.44	29,360
Dec. 30 and 31, 1879	3		95	31.75	10.50	..do...	540	10.94	1,336	1,341	6,732	195.86	70.86	30,000
Total	401 rounds.													

REMARKS.—Distance of first wire target from muzzle of gun 59 feet; distance between first and second targets 100 feet.

APPENDIX 9 *c*.

REPORT OF THE TRIAL OF THE 8-INCH BREECH-LOADING RIFLE No. 1.

A full description of this gun and of the carriage used in its test, with details of construction, will be found in the report of the Constructor of Ordnance for 1878. (See Report of the Chief of Ordnance, 1878, pages 359, 378, 379.)

POWDERS.

The powders used were four varieties of the Du Pont's hexagonal, three of which, the F. P. B., G. H., and F. P. C., were of a density of 1.785, granulation 67. The remaining variety, and that mainly used, was the E. V. J., density 1.750, granulation 72.

PROJECTILES.

The projectiles were elongated cast-iron cored shot, with soft metal sabots of the Butler pattern, and of an average weight of 180 pounds. Full descriptions of this projectile are given in previous reports of the board, and the detailed weights and dimensions are given in the appended tables.

EXPERIMENTS AND TESTS.

Prior to the commencement of the test for endurance, seven preliminary rounds were fired, using projectiles weighing about 185 pounds and powder charges varying from 15 to 30 pounds. For record of this firing, see Table No. 1.

The preliminary test proving satisfactory, the experimental test for endurance was begun, using throughout battering charges of 35 pounds of powder and projectiles averaging in weight 180 pounds, with five exceptional rounds of 25 and 30 pounds of powder used in the test of gas checks.

Of the 489 rounds fired using full battering charges of 35 pounds, the powders used, and number of rounds with each variety, with the corresponding average weights of projectiles, pressures, muzzle velocities and energies, were as follows:

Powder.	Number of rounds.	Average weight of projectiles.	Average pressure per □″ of bore.	Average velocity at muzzle.	Total average energy at muzzle.	Average energy at muzzle per inch of shot's circumference.
		Lbs.	*Lbs.*	*Feet.*	*Foot-tons.*	*Foot-tons.*
F. P. B	86	181.4	26. 216	1339. 5	2256. 2	90. 34
G. H	38	181.	26. 133	1308.	2146. 6	85. 95
F. P. C	53	180.	27. 275	1405. 3	2464. 2	98. 66
E. V. J	312	179.5	34. 081	1415. 4	2492. 8	99. 81

An average muzzle energy, with all powders of battering charge, 35 pounds, and an average weight of projectile of 180 pounds was 2,369 foot-tons.

An average of the powders of higher density and coarser granulation shows a velocity of 1,351 feet, with a corresponding pressure of 26,541 pounds, while that of the E. V. J., of slightly lower density and slightly finer granulation, shows an average velocity of 1,415 feet, with a pressure of 34,081 pounds; a pressure entirely within the capacity of the gun. In view of this satisfactory result, the board would recommend for the service of guns of this class a powder based upon this (E. V. J.) as a standard.

EFFECTS ON THE GUN.

The first round with battering charge, being the eighth fired from the gun, developed a slight escape of gas on the exterior of the gas-check in the direction of the coil-weld of the tube, the escape exhibiting itself by powder stains on the face of gas-check and tube, and indicating very clearly a defect in the coil-weld at that point. The first gas-check used was a Broadwell steel ring. This was subsequently changed for one of brass, then one of copper, and finally for a check of steel and copper combined. From these changes and a slight reaming out of the seat of the gas-check, the escape of gas varied until the two hundred and thirty-fifth round, when the combined gas-check was so modified by lengthening and thinning the lip to more fully cover up the weld defect. The gun was then fired up to the four hundred and fifth round before any further escape of gas was observed. From this to the four hundred and seventy-eighth round it was fired with slight escape of gas, and from this round to the five hundred and first, which was the limit fixed upon for the endurance of the gun, no escape of gas occurred. The bore proper shows slight erosions at seat of shot, but the increase in diameter, as shown by the different star-gauge records accompanying this report, is comparatively slight, amounting to 0.009 of an inch.

EFFECTS ON THE CARRIAGE.

The carriage from which this gun was fired throughout the trials was carriage No. 3, as described in the report of the Chief of Ordnance of 1877. It worked well in all respects, and sustained no injury during the trials.

CONCLUSIONS.

The endurance of this system of gun construction and the endurance as well as the successful manipulation of the breech mechanism, in the opinion of the board, have been satisfactorily established, and, in its judgment, the department is warranted in their adoption for future new constructions as well as in future conversions of smooth-bore into rifled guns.

TABLE No. 1.—*Record of firings with an experimental 8-inch breech-loading rifle, from August* 1, 1878, *to July* 11, 1879, *inclusive, at Sandy Hook, New Jersey.*

Date.	Number of round.	Charge. Kind of powder.	Charge. Cartridge. Weight.	Charge. Cartridge. Height.	Charge. Cartridge. Diameter.	Projectile. Kind.	Projectile. Weight.	Projectile. Length.	Projectile. Diameter.	Velocities at 110 feet from muzzle of gun.	Maximum pressures per square inch at surface of bore.	Remarks.
1878.			*Pounds.*	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Inches.*	*Feet.*	*Pounds.*	
Aug. 1	1		15	10	7.25	Butler	185	....	7.95	....	8,000	
Aug. 1	2		20	13¼	7.25	....do	185	....	7.95	....	20,000	
Aug. 1	3		20	13¼	7.25	....do	185	....	7.95	....	14,500	These shot were fired into the butt, and were preliminary to the test of the gun for endurance.
Aug. 1	4		25	16¼	7.25	....do	184	....	7.95	....	25,000	
Aug. 1	5	Du Pont's hexagonal F. P. B. Density, 1.785; granulation, 67.	25	16¼	7.25	....do	185	....	7.95	....	21,500	
Aug. 2	6		30	19¼	7.25	....do	183	....	7.95	....	21,500	
Aug. 2	7		30	19¼	7.25	....do	185	....	7.95	1,220	22,000	
Aug. 8	14		30	19¼	7.25	....do	186	....	7.95	1,331	29,500	These charges were exceptional, being used in the test of gas-check and during the firing of the gun for endurance.
Aug. 17	27		25	16¼	7.25	....do	185	....	7.95	....	15,500	
Dec. 5	42		30	19¼	7.25	....do	183	....	7.95	....	24,500	
June 11	135	Du Pont's hexagonal E. V. J. Density, 1.750; granulation, 72.	30	19¼	7.25	....do	180	....	7.95	1,272	27,000	
July 9	171		25	16¼	7.25	....do	180	....	7.95	....	....	

DESCRIPTION OF GUN.—An 8-inch breech-loading rifle, converted from a 10-inch Rodman smooth-bore by lining with a steel-jacketed coiled wrought-iron tube, inserted from the breech; jacket of the tube being prolonged to the rear and adapted for reception of the round wedge fermeture. Caliber, 8 inches. Total length of gun, 147.25 inches. Length of rifled portion of bore, including bevel, 101.25 inches. Length of chamber, 22 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and lands, 15 each. Twist uniform, one turn in forty feet. Weight of gun, 17,075 pounds.

AVERAGES.

TABLE NO. 2.—*Record of firings for endurance with an experimental 8-inch breech-loading rifle, from August 1, 1878, to December 4, 1879, inclusive, at Sandy Hook, New Jersey.*

Date.	Number of shots.	Charge.				Projectile.			Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulangé chronograph.	Velocities at the muzzle.	Energy of projectile.		Gas pressure per square inch of bore, as taken with Rodman's internal-pressure gauge.	Remarks.
		Kind of powder.	Cartridge.								Total at the muzzle.	Per inch of shot's circumference.		
			Weight.	Height.	Diameter.	Kind.	Weight.	Diameter.			$\frac{WV^2}{2g2240}$	$\frac{WV^2}{4g\pi R2240}$		
			Lbs.	In.	In.		Lbs.	In.	Feet.	Feet.	Ft. tons.	Foot-tons.	Lbs.	
October 17, 1878	1	Du Pont's hexagonal F. P. B. Density, 1,785; granulation, 67.	35	22¼	7.25	Butler	175	7.95	1,303	1,310	2,082	83.35	23,500	During the firings, gas-checks of steel (Broadwell), of copper, and of copper and steel, were employed. 4.58 feet was the limit of recoil for the gun. Distance of first wire target from the gun, 60 feet; distance between first and second targets, 100 feet. Average velocity (at 110 feet) with F. P. B. powder, 35 pounds, projectile 181.4 pounds, was 1,332 feet, corresponding pressure 26,216 pounds; with G. H. powder, 35 pounds, projectile 181 pounds, was 1,301 feet, corresponding pressure 26,133 pounds; with F. P. C.
October 17, 1878, and June 11, 1879	2		35	22¼	7.25	...do	178	7.95	1,306	1,313	2,127	85.17	24,500	
May 23 and 27, and June 11, 1879	4		35	22¼	7.25	...do	179	7.95	1,342	1,349	2,258	90.41	25,000	
October 25, 1878, May 9, 13, and 21, and June 11, 1879	8		35	22¼	7.25	...do	180	7.95	1,339	1,347	2,264	90.65	26,750	
October 17 and 25, 1878, May 8, 9, and 27, and June 11, 1879	11		35	22¼	7.25	...do	181	7.95	1,347	1,355	2,304	92.24	27,122	
August 22 and 23, and November 1, 1878, and May 8, 9, 13, 21, 23, 27, and 28, 1879	29		35	22¼	7.25	...do	182	7.95	1,350	1,358	2,327	93.16	26,200	
August 22, and December 5, 1878, and May 9, 21, 23, and 28, 1879	8		35	22¼	7.25	...do	183	7.95	1,342	1,350	2,312	92.57	26,188	
August 8 and 9, and October 18, 1878, and May 21, 1879	9		35	22¼	7.25	...do	184	7.95	1,319	1,326	2,242	89.79	26,777	
August 2, 8, and 9, 1878	7		35	22¼	7.25	...do	185	7.95	1,313	1,320	2,234	89.47	25,428	
August 8 and 17, 1878	7		35	22¼	7.25	...do	186	7.95	1,336	1,342	2,322	92.975	27,643	
June 6 and 10, 1879	1	Du Pont's hexagonal G. H. Density, 1,785; granulation, 67.	35	22¼	7.25	...do	177	7.95	....	......	......	....	28,500	
	2		35	22¼	7.25	...do	178	7.95	1,321	1,328	2,176	87.13	28,000	
	3		35	22¼	7.25	...do	179	7.95	....	......	......	....	....	
	8		35	22¼	7.25	...do	180	7.95	1,312	1,319	2,171	86.92	24,800	
	5		35	22¼	7.25	...do	181	7.95	....	......	......	....	....	
	14		35	22¼	7.25	...do	182	7.95	1,293	1,300	2,132	85.37	25,333	
	5		35	22¼	7.25	...do	183	7.95	1,264	1,271	2,049	82.05	24,000	

AVERAGES.

TABLE No. 2.—*Record of firings for endurance with an experimental 8-inch breech-loading rifle, from August 1, 1878, to December 4, 1879, inclusive, at Sandy Hook, New Jersey.*

Date.	Number of shots.	Charge. Kind of powder.	Charge. Cartridge. Weight.	Charge. Cartridge. Height.	Charge. Cartridge. Diameter.	Projectile. Kind.	Projectile. Weight.	Projectile. Diameter.	Mean observed velocities of the projectile at 110 feet from the muzzle of the gun, as recorded by Le Boulangé' chronograph.	Velocities at the muzzle.	Energy of projectile. Total at the muzzle. $\frac{WV^2}{2g\,2240}$	Energy of projectile. Per inch of shot's circumference. $\frac{WV^2}{4gu\,R2240}$	Gas pressure per square inch of bore, as taken with Rodman's internal-pressure gauge.	Remarks.
			Lbs.	In.	In.		Lbs.	In.	Feet.	Feet.	Ft. tons.	Foot-tons.	Lbs.	
November 11, 12, and 13, 1879	2	Du Pont's hexagonal F. P. C. Density, 1,785; granulation, 67.	35	22¼	7.25	...do....	175	7.95	1,403	1,411	2,415	96.70	25,500	powder, 35 pounds, projectile 180 pounds, was 1,397 feet, corresponding pressure. 27,275 pounds; with E. V. J. powder, 35 pounds, projectile 179.48 pounds, was 1,407 feet, corresponding pressure 34,081 pounds.
	1		35	22¼	7.25	...do....	177	7.95	1,446	1,455	2,598	104.00	31,500	
	14		35	22¼	7.25	...do....	178	7.95	1,409	1,417	2,478	99.20	27,667	
	4		35	22¼	7.25	...do....	179	7.95	1,387	1,395	2,415	96.68	26,875	
	11		35	22¼	7.25	...do....	180	7.95	1,388	1,396	2,432	97.36	28,000	
	9		35	22¼	7.25	...do....	181	7.95	1,359	1,367	2,345	93.88	27,167	
	8		35	22¼	7.25	...do....	182	7.95	....	......	....	....	24,500	
	3		35	22¼	7.25	...do....	183	7.95	....	......	....	....	27,500	
	1		35	22¼	7.25	...do....	184	7.95	....	......	....	....	....	
December 2, 1879	1		35	22¼	7.25	...do....	173	7.95	....	......	....	....	20,500	The mean of all with all powders, using 35-pound charges, was 1,370 feet velocity, and 30,007 pounds pressure; average weight of projectiles, 179.96 pounds.
June 18 and 21, July 9, August 15, November 25 and 28, and December 2, 1879	9		35	22¼	7.25	...do....	175	7.95	1,420	1,428	2,474	99.05	32,625	
November 28, and December 3 and 4, 1879	8		35	22¼	7.25	...do....	176	7.95	....	......	....	....	....	
June 11 and 21, and October 11, 17, and 18, November 10, 25, 26, and 28, and December 3 and 4, 1879	33		35	22¼	7.25	...do....	177	7.95	1,411	1,420	2,474	99.06	32,944	
June 11 and 21, July 9, October 7, 10, 16, and 17, November 10, 25, and 28, and December 3 and 4, 1879	54		35	22¼	7.25	...do....	178	7.95	1,418	1,426	2,509	100.50	32,033	
November 10, 25, 26, and 28, and De-														

cember 3 and 4, 1879	39	Du Pont's hexagonal E.V.J. Density, 1,750; granulation, 72.	35	22¼	7.25	...do	179	7.95	1,407	1,415	2,484	99.47	30,278
June 11, 18, and 21, July 9 and 11, August 13, 15, and 27, October 7, 10, 17, and 18, November 8, 10, 25, and 28, and December 3 and 4, 1879	70		35	22¼	7.25	...do	180	7.95	1,402	1,410	2,481	99.32	35,553
June 18, August 13, 14, and 15, October 9, 10, 16, and 18, November 8, 10, 25, and 28, and December 3 and 4, 1879	54		35	22¼	7.25	...do	181	7.95	1,406	1,414	2,509	100.40	35,959
June 18, July 11, October 16 and 18, November 8, 10, 25, and 28, and December 4, 1879	28		35	22¼	7.25	...do	182	7.95	1,406	1,414	2,523	101.00	35,250
June 18, August 13, October 10 and 11, November 8, 10, and 25, and December 4, 1879	11		35	22¼	7.25	...do	183	7.95	....	......	....	....	40,250
August 13, 1879	1		35	22¼	7.25	...do	184	7.95	....	......	....	....	34,500
July 9, October 11, November 10, and December 4, 1879	4		35	22¼	7.25	...do	185	7.95	1,388	1,396	2,499	100.06	32,500
Total	489												

DESCRIPTION OF GUN.—An 8-inch breech-loading rifle, converted from a 10-inch Rodman smooth-bore by lining with a steel-jacketed coiled wrought-iron tube, inserted from the breech, jacket of the tube being prolonged to the rear and adapted for reception of the round-wedge fermeture. Caliber, 8 inches. Total length of gun, 147.25 inches. Length of rifled portion of bore, including bevel, 101.25 inches. Length of chamber, 22 inches. Diameter of bore, including grooves, 8.15 inches. Number of grooves and ands, 15 each. Twist uniform, one turn in forty feet. Weight of gun, 17,075 pounds.

TABLE No. 3.—*Table of enlargements of 8-inch breech-loading rifle No. 1.*

Inches from muzzle.	Original play of tube.*	Original diameter of bore.	Enlargements of bore, including "setting up" of tube, after— A total of 46 rounds.	A total of 72 rounds.	A total of 92 rounds.	A total of 140 rounds.	A total of 265 rounds.	A total of 326 rounds.	A total of 375 rounds.	A total of 436 rounds.	A total of 501 rounds.
	Inches.	*Inches.*									
99		7.990	0.000	0.001	0.001	0.002	0.005	0.005	0.005	0.006	0.006
98		.990	.000	.001	.001	.002	.005	.005	.005	.005	.005
97		.990	.000	.001	.001	.002	.005	.005	.005	.005	.005
96		.990	.000	.002	.002	.002	.005	.005	.005	.005	.005
95		.990	.000	.002	.003	.003	.005	.005	.005	.005	.005
94		.990	.001	.003	.003	.003	.006	.006	.006	.006	.006
93		.990	.001	.003	.003	.003	.006	.006	.006	.006	.006
92		.990	.001	.003	.003	.003	.006	.006	.006	.008	.008
91		.990	.001	.003	.003	.003	.005	.006	.006	.006	.006
90		.990	.000	.002	.002	.003	.005	.005	.006	.006	.006
89		.990	.000	.001	.002	.002	.004	.004	.005	.005	.005
88		.990	.000	.000	.001	.001	.004	.004	.004	.004	.004
87		.990	.000	.001	.001	.001	.004	.004	.004	.004	.004
86		.990	.000	.002	.002	.002	.005	.005	.005	.005	.005
85		.991	.002	.004	.004	.004	.007	.007	.007	.007	.007
84		.993	.002	.003	.004	.004	.006	.006	.006	.006	.006
83		.995	.002	.003	.003	.003	.006	.006	.006	.006	.006
82		.995	.005	.005	.005	.005	.008	.008	.008	.008	.008
81		.996	.004	.006	.006	.006	.009	.009	.009	.009	.009
80		.996	.004	.005	.005	.005	.008	.009	.009	.009	.009
78		.997	.003	.004	.004	.004	.008	.008	.009	.009	.009
76		.997	.002	.003	.003	.003	.008	.008	.008	.008	.008
74		.996	.003	.005	.005	.005	.008	.008	.008	.008	.008
72		.996	.002	.004	.004	.004	.007	.007	.008	.008	.008
70		.995	.001	.002	.003	.003	.005	.005	.008	.008	.005
68		.993	.002	.002	.003	.003	.005	.005	.006	.006	.006
66		.995	.000	.002	.002	.002	.004	.004	.004	.004	.004
64		.995	.001	.002	.002	.002	.005	.005	.005	.005	.005
62		.995	.001	.004	.004	.004	.005	.005	.006	.006	.006
60		.995	.002	.004	.004	.004	.005	.005	.006	.006	.006
58		.995	.002	.004	.004	.004	.005	.005	.008	.008	.008
56		.995	.002	.004	.004	.004	.005	.005	.007	.007	.007
54		.995	.002	.003	.003	.003	.005	.005	.005	.005	.005
52		.995	.002	.002	.002	.002	.004	.004	.005	.005	.005
50		.995	.002	.002	.002	.002	.004	.004	.004	.004	.004
48		.995	.001	.002	.002	.002	.003	.003	.004	.004	.004
46		.995	.001	.002	.002	.002	.003	.003	.003	.003	.003
44		.995	.001	.001	.001	.001	.003	.003	.003	.003	.003
42		.995	.001	.001	.001	.001	.003	.003	.003	.003	.003
40		.995	.001	.001	.001	.001	.003	.003	.003	.003	.003
38		.996	.000	.000	.000	.000	.003	.003	.003	.003	.003
36		.996	.000	.000	.000	.000	.004	.004	.004	.004	.004
34		.996	.000	.001	.001	.001	.004	.004	.004	.004	.004
32		.996	.000	.001	.001	.001	.004	.004	.004	.004	.004
30		.996	.000	.000	.000	.000	.004	.004	.004	.004	.004
28		.996	.000	.001	.001	.001	.004	.004	.004	.004	.004
26		.996	.000	.000	.000	.000	.004	.004	.004	.004	.004
24		.996	.000	.001	.001	.001	.004	.004	.004	.004	.004
22		.996	.000	.001	.001	.001	.004	.004	.004	.004	.004
20		.996	.000	.001	.001	.001	.004	.004	.004	.004	.004
18		.996	.000	.002	.002	.002	.004	.004	.004	.004	.004
16		.996	.000	.002	.002	.002	.004	.004	.004	.004	.004
14		.996	.000	.002	.002	.002	.004	.004	.004	.004	.004
12		.995	.001	.003	.003	.003	.005	.005	.005	.005	.005
10		.995	.000	.003	.003	.003	.005	.005	.005	.005	.005
8		.995	.000	.002	.002	.002	.005	.005	.005	.005	.005
6		.995	.000	.002	.002	.002	.005	.005	.005	.005	.005
4		.995	.000	.002	.002	.002	.005	.005	.005	.005	.005
2		.995	.000	.001	.001	.001	.005	.005	.005	.005	.005
1		.995	.000	.001	.001	.001	.005	.005	.005	.005	.005

*See Table No. 2, page 364, Report of the Chief of Ordnance, 1878.

APPENDIX 9 *d*.

REPORT OF THE TRIAL OF AN 8-INCH EXPERIMENTAL MUZZLE-LOADING CHAMBERED RIFLE (No. 28).

(Two Plates.)

A full description of this gun, converted from a 10-inch Rodman smooth-bore, giving dimensions and capacity of powder-chamber as well as other detailed information, will be found in the Report of the Constructor of Ordnance for 1880. (See Appendix 8 *d*.)

CARRIAGE.

The carriage used throughout the 119 rounds fired to date was that known as the "altered carriage No. 1," arranged with the compressor screw and recoil rail, a full description of which is given in the report of the Ordnance Board for 1877. (See Report of the Chief of Ordnace for that year, pages 627, 628, with accompanying plate.)

POWDER.

The powder used, with the exception of one round, was Du Pont's hexagonal F. P. C., density 1,785, granulation 67; the general uniformity of results both in pressures and velocities shows it to be of careful manufacture, and power attained is evidence of its suitability to a conversion of this nature. The exceptional round was with 45 pounds of hexagonal E. V. J., from the same mills; it is of slightly lower density and finer granulation, and giving increased pressure with the lighter charge, its further use was abandoned.

PROJECTILES.

The projectiles used, with the exception of eight rounds, were of the Butler pattern, averaging 180 pounds in weight, very nearly, and similar in all respects to the projectiles of that pattern usually employed in 8-inch muzzle-loading rifles. The exceptional eight rounds were in test of the longer Navy shells, which, as will be seen from the appended table, gave unsatisfactory results as regards steadiness of flight.

EXPERIMENTS AND TESTS.

The test was begun with the regular service charge for non-chambered guns of this caliber, 35 pounds, and gradually increased by five-pound additions until the maximum charge intended for the chamber, 55 pounds, was reached, when, after a limited number of trial shots and under the instructions of the Chief of Ordnance, one hundred rounds in all were fired with this weight of powder. The results are shown in the appended Table No. 1.

The effect of chambering, and the consequent increase in velocity, upon the accuracy of the 8-inch rifle was, in a measure, determined by a target of ten rounds at a range of a mile. The result is given in Table No.

3 and the accompanying plotted target, and, as should be expected, is in favor of the chambered gun.

Upon the completion of this series the vent piece was removed from its normal position, the vent aperture closed with a copper plug, and a new vent piece inserted in a vertical plane, containing the axis of the bore, and at a distance of 104″.85 from the face of the muzzle, a point slightly in rear of the center of volume of the powder chamber. Ten rounds with full charges were then fired to note the effect of this change of position of the vent, and the results are embodied in the appended Table No. 4. It will be seen that the average velocity was reduced by 10 feet, with a proportional decrease of pressure.

EFFECTS ON THE GUN AND CARRIAGE.

Notwithstanding the somewhat higher pressures due to the increased powder charge and considerably higher velocities obtained as compared to the unchambered gun, there was but slight wearing of the bore. The enlargements, as indicated by the star gauge, are shown in Table No. 6. The gun remains in entirely serviceable condition.

The carriage had been used previously in the test of other guns, having been subjected altogether to a record of 122 rounds prior to the mounting of this gun. At the fourteenth round of this series one of the front guides of the upper carriage broke and was replaced; at the fifteenth the connecting rod for the friction plate broke and was repaired. With these exceptions the carriage worked satisfactorily.

CONCLUSIONS.

This experiment shows that with pressures entirely within the limits of safety the increased velocity due to chambering has increased the power of the 8-inch rifle about one-third, and that the increase of power is accompanied by an increased accuracy of fire. The wear of bore incident to the higher charge with the one hundred and eleven rounds fired seems no greater than that in the unchambered gun with the 35-pound charge.

The board, therefore, recommends the adoption of the system of chambering in all future conversions or new constructions of this and of 11-inch calibers. In higher calibers the system has already received the approval of the department.

TABLE No. 1.—*Record of firings with an experimental* 8-*inch muzzle-loading chambered rifle, No.* 28, *from December* 12, 1879, *to August* 19, 1880, *inclusive, at Sandy Hook, New York Harbor.*

DESCRIPTION OF GUN.—A rifle converted from a 10-inch Rodman cast-iron smooth-bore by lining with a jacketed wrought-iron coiled tube, inserted from the rear, or breech; caliber, 8 inches; length of bore (including chamber), 116.98 inches; length of rifling, 88.963 inches; total length of chamber, 28.017 inches; diameter of chamber, 9 inches; volume of chamber, 1,650 cubic inches; full powder capacity of chamber, 62 pounds; depth of grooves, 0.073 inch; number of grooves and lands, 15; twist uniform, one turn in 60 calibers; weight of gun, 16,065 pounds.

Date.	Number of round.	Charge.				Projectile.		
		Kind of powder.	Cartridge.			Kind.	Weight.	Length.
			Weight.	Height.	Diameter.			
1879.			Pounds.	Inches.	Inches.		Pounds.	Inches.
Dec. 12	1, 2	Du Pont's hexagonal F. P. C.; density, 1.785; granulation, 67	35	22	7.15	Butler cored shot.	184	20
12	3, 4		45	26	8.50	....do	182	20
12	5, 6		50	30	8.50	....do	181	20
12	7, 8		55	34	8.50	....do	181	20
1880.								
July 15	17	Du Pont's hexagonal E. V. J.; density, 1.750; granulation, 72	45	26	8.50	....do	180	20
29	29	Du Pont's hexagonal F. P. C.; density, 1.785; granulation, 67	55	34	8.50	....do	179	20
29	33		55	34	8.50	....do	182	20
Aug. 12	35, 36		55	34	8.50	....do	180	20
17	37		55	34	8.50	....do	180	20
17	41		55	34	8.50	....do	179	20
17	45		55	34	8.50	....do	178	20
17	50		55	34	8.50	....do	180	20
17	55		55	34	8.50	....do	180	20
18	60		55	34	8.50	....do	180	20
18	65		55	34	8.50	....do	180	20
18	70		55	34	8.50	....do	180	20
18	75		55	34	8.50	....do	180	20
18	80		55	34	8.50	....do	180	20
18	85		55	34	8.50	....do	180	20
18	90		55	34	8.50	....do	180	20
19	95		55	34	8.50	....do	180	20
19	100		55	34	8.50	....do	179	20
19	105		55	34	8.50	....do	179	20
19	108		55	34	8.50	....do	177	20

TABLE No. 1.—*Record of firings, &c.*—Continued.

Date.	Number of round.	Mean observed velocities of the projectile at 109 feet from the muzzle of the gun, as recorded by Le Boulengé chronograph.	Velocities at the muzzle.	Muzzle energy.				Gas pressure per square inch of bore, as taken with Rodman's internal pressure gauge.
				Total.	Per inch of shot's circumference.	Per square inch of cross-section.	Per pound of powder.	
1879.		*Feet.*	*Feet.*	*Foot-tons.*	*Foot-tons.*	*Foot-tons.*	*Foot-tons.*	*Pounds.*
Dec. 12	1, 2	1, 157	1, 163	1, 725	69. 08	34. 76	49. 29	15, 750
12	3, 4	1, 433	1, 442	2, 623	105. 03	52. 85	58. 30	26, 500
12	5, 6	1, 534	1, 544	2, 991	119. 76	60. 26	59. 82	31, 500
12	7, 8	1, 634	1, 645	3, 396	135. 97	68. 42	61. 75	36, 500
1880.								
July 15	17	Lost.	....	....	....	....	....	41, 000
29	29	1, 613	1, 624	3, 273	131. 03	65. 93	59. 50	39, 000
29	33	1, 634	1, 645	3, 415	136. 72	68. 79	62. 09	37, 500
Aug. 12	35, 36	1, 628	1, 639	3, 353	134. 23	67. 54	60. 96	36, 500
17	37	1, 638	1, 649	3, 394	135. 90	68. 38	61. 71	37, 000
17	41	1, 642	1, 653	3, 392	135. 82	68. 34	61. 68	39, 500
17	45	1, 653	1, 665	3, 419	136. 90	68. 88	62. 17	36, 500
17	50	1, 603	1, 614	3, 250	130. 12	65. 47	59. 09	36, 000
17	55	1, 629	1, 640	3, 357	134. 40	67. 62	61. 03	36, 000
18	60	1, 637	1, 648	3, 390	135. 73	68. 30	61. 64	37, 500
18	65	1, 644	1, 655	3, 419	136. 90	68. 88	62. 17	38, 000
18	70	1, 618	1, 629	3, 311	132. 58	66. 71	60. 21	37, 500
18	75	1, 597	1, 608	3, 225	129. 14	64. 98	58. 64	37, 500
18	80	1, 633	1, 644	3, 373	135. 07	67. 96	61. 34	41, 000
18	85	1, 610	1, 621	3, 278	131. 26	66. 04	59. 61	38, 000
18	90	1, 638	1, 649	3, 394	135. 90	68. 38	61. 71	38, 000
19	95	1, 631	1, 642	3, 365	134. 73	67. 79	61. 18	41, 000
19	100	1, 637	1, 648	3, 372	135. 00	67. 92	61. 30	38, 000
19	105	1, 598	1, 609	3, 212	128. 60	64. 70	58. 39	40, 000
19	108	1, 613	1, 624	3, 237	129. 59	65. 20	58. 85	....

REMARKS.

Distance of the first wire target from muzzle of gun, 59 feet; distance between first and second targets, 100 feet.

The cartridge-bag at the beginning of the trial was ripped open along the longitudinal seam and refastened with a steel wire. Subsequently bags 8.5 inches in diameter were used, and the surplus material, after allowing 7.5 inches for loading, was gathered and fastened by the wire. After the cartridge was pushed to the bottom of the bore, the wire was withdrawn and the cartridge then pushed into the chamber, when longer than it, as in the 55-pound charges, leaving the powder loose in the chamber, the shot in each case being set home only to the end of the rifling. Allowing 30 cubic inches of volume per pound of powder, fifty-five pounds is the maximum capacity of the chamber.

Mean weight of projectiles (using 55-pound charges), 179.85 pounds.

Mean velocity at muzzle (using 55-pound charges), 1,641 feet.

Mean maximum pressure (using 55-pound charges), 37,809 pounds.

Mean energy at muzzle (using 55-pound charges), 3,357 foot-tons.

TABLE No. 2.—*Record of firings with an experimental 8-inch muzzle-loading chambered rifle, No. 28, from January 21 to April 9, 1880 (inclusive), at Sandy Hook, New Jersey.*

DESCRIPTION OF GUN.—A rifle converted from a 10-inch Rodman cast-iron smooth-bore by lining with a jacketed wrought-iron coiled tube, inserted from the rear, or breech; caliber, 8 inches; length of bore (including chamber), 116.98 inches; length of rifling, 88.963 inches; total length of chamber, 28.017 inches; diameter of chamber, 9 inches; volume of chamber, 1,650 cubic inches; full powder capacity of chamber, 62 pounds; depth of grooves, 0.073 inch; number of grooves and lands, 15; twist uniform, one turn in 60 calibers; weight of gun, 16,065 pounds.

Date.	Number of round.	Charge.				Projectile.			Mean observed velocities of the projectile at 109 feet from the muzzle of the gun as recorded by Le Boulenge chronograph.	Gas pressure per square inch of bore, as taken with Rodman's internal pressure gauge.	Elevation.	Remarks.
		Kind of powder.	Cartridge. Weight.	Cartridge. Height.	Cartridge. Diameter.	Kind.	Weight.	Length.				
1880.			Lbs.	Ins.	Ins.		Lbs.	Ins.	Feet.	Lbs.	°	
Jan. 21	9	Du Pont's hexagonal, F. P. C.; density, 1.785; granulation, 67.	50	30	8.5	Butler Navy shells filled with sand to bring them up to the standard weight.	180	23.25	....	37,000	10	Fired out to sea; slightly irregular flight; time of flight, 14¾″.
	10		55	34	8.5		180	23.25	....	45,000	10	Fired out to sea; clear, smooth sound; time of flight, 15″.
Jan. 22	11		55	34	8.5		180	23.25	....	38,500	10	Fired out to sea; slightly irregular flight; range, 5,140 yards.
	12		55	34	8.5		180	23.25	....	....	10	Fired out to sea; irregular flight; range lost.
	13		55	34	8.5		180	23.25	....	40,500	10	Fired out to sea; irregular flight; range, 4,955 yards.
Apr. 9	14		55	34	8.5		179	23.25	....	....	10	Fired out to sea; slightly irregular flight; time of flight, 14¾″.
	15		55	34	8.5		179	23.25	....	....	10	Fired out to sea; slightly irregular flight; time of flight, 15″.
	16		55	34	8.5		179	23.25	1,633	25,000	−¾	Fired into sand butt.

NOTES.—The shells used in rounds 9 to 13 inclusive were filled with sand to bring them up to 180 pounds weight; those used in rounds 14 to 16 inclusive were filled with sand to bring them up to the weight of a loaded shell. The shell used in round No. 14 had copper band ⅜ inch wide, placed around cylindrical portion of shell, 14¾ inches from bottom of sabot, or 1 inch from the base of head or point of shell; in rounds 15 and 16 a similar band ¾ inch wide was used. At round No. 14, front guide on upper carriage broke and was replaced. At round No. 15, connecting rod for friction plate broke and was repaired.

TABLE No. 3.—*Record of target firing with an experimental 8-inch muzzle-loading chambered rifle, No. 28, at Sandy Hook, New Jersey, July 15, 1880; distance of target from muzzle of gun, one mile.*

DESCRIPTION OF GUN.—A rifle converted from a 10-inch Rodman cast-iron smooth-bore by lining with a jacketed wrought-iron coiled tube, inserted from the rear, or breech; caliber, 8 inches; length of bore (including chamber), 116.98 inches; length of rifling, 88.963 inches; total length of chamber, 28.017 inches; diameter of chamber, 9 inches; volume of chamber, 1,650 cubic inches; full powder capacity of chamber, 62 pounds; depth of grooves, 0.073 inch; number of grooves and lands, 15; twist uniform, one turn in 60 calibers; weight of gun, 16,065 pounds.

No. of round.	Powder.		Projectile.		Elevation.	Deviation from center of target in yards.				Deviation from center of impact in yards.				Remarks.
						Vertical.		Horizontal.		Vertical.		Horizontal.		
	Kind.	Weight.	Kind.	Weight.		Above.	Below.	Right.	Left.	Above.	Below.	Right.	Left.	
19	Du Pont's hexagonal, F. P. C.; density, 1.785; granulation, 67.	55	Butler cored shot	180	2° 15′	2.66	....	....	2.89	2.09	....	....	.006	Target 20 x 40 feet, made of 1-inch spruce boards.
20		55	......do	180	2° 10′	2.00	....	....	3.00	1.42	....	....	.12	
21		55	......do	180	2° 10′	1.05	....	....	2.39	.48	....	.49	....	
22		55	......do	180	2° 10′	1.36	....	....	2.39	.78	....	.49	....	
23		55	......do	180	2° 10′	....	.72	....	3.66	....	1.29	....	.78	
24		55	......do	180	2° 10′	....	.39	....	2.39	....	.96	.49	....	
25		55	......do	180	2° 10′	1.22	....	....	2.66	.65	....	.22	....	
26		55	......do	180	2° 10′	....	1.66	....	2.39	....	2.24	.49	....	
27		55	......do	180	2° 10′	1.44	....	....	3.66	1.20	....	....	.78	
28		55	......do	180	2° 10′	....	1.22	....	3.39	....	1.79	....	.50	

Mean vertical deviation from center of impact, 1.26 yards; mean horizontal deviation from center of impact, .44 yards; mean deviation from center of impact, 1.33 yards

TABLE No. 4.—*Record of firings with an experimental 8-inch muzzle-loading chambered rifle, No. 28 (central vent), August 31, 1880, at Sandy Hook, New Jersey.*

Number of round.	Charge.				Projectile.			Mean observed velocities of the projectile at 109 feet from the muzzle of the gun, as recorded by Le Boulengé chronograph.	Gas pressure per square inch of bore, as taken with Rodman's internal pressure gauge.	Remarks.
	Kind of powder.	Cartridge.			Kind.	Weight.	Length.			
		Weight.	Height.	Diameter.						
		Pounds.	*Inches.*	*Inches.*		*Pounds.*	*Inches.*	*Feet.*	*ounds.*	
110	Du Pont's hexagonal F. P. C.; density, 1.785; gran., 67.	55	34	8.5	Butler cored shot.	178	20	1,634	35,000	After the one hundred and ninth round, the original vent aperture was closed with a copper screw plug, and a new aperture made 104.85 inches from the face of the muzzle, the axis of the new vent being in the vertical plane passing through the axis of the bore. The details of the new bushing are the same as in service 8-inch rifles.
111	......do	55	34	8.5	....do	182	20	1,622	35,500	
112	......do	55	34	8.5	....do	178	20	1,619	32,500	
113	......do	55	34	8.5	....do	182	20	1,597	41,000	
114	......do	55	34	8.5	....do	178	20	1,608	39,000	
115	......do	55	34	8.5	....do	182	20	1,615	37,500	
116	......do	55	34	8.5	....do	177	20	1,627	37,000	
117	......do	55	34	8.5	....do	182	20	1,622	36,000	
118	......do	55	34	8.5	....do	181	20	1,614	35,000	
119	......do	55	34	8.5	....do	181	20	1,618	32,500	

DESCRIPTION OF GUN.—A rifle converted from a 10″ Rodman cast-iron smooth-bore by lining with a jacketed wrought-iron coiled tube inserted from the rear or breech; caliber, 8 inches; length of bore (including chamber), 116″.98; length of rifling, 88″.963; total length of chamber, 28″.017; diameter of chamber, 9″; volume of chamber, 1,650 cubic inches; full powder capacity of chamber, 62 pounds; depth of grooves, 0″.073; number of grooves and lands, 15; twist uniform—one turn in 60 calibers; weight of gun, 16,065 pounds.

TABLE No. 5—*Showing relative energies of the 8-inch experimental chambered rifle, the 9-inch English service rifled muzzle-loader, of 12 tons, and the 8-inch muzzle-loading unchambered rifle, at distances up to 3,000 yards.*

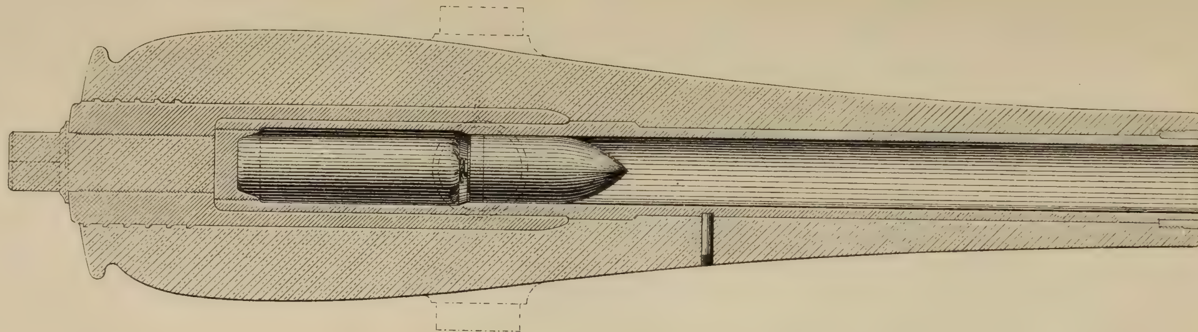
Kind of gun.	Weight of powder, pounds.	Weight of projectile, pounds.	Velocity, feet.				Energy, foot-tons.				Penetration, inches.			
			At muzzle.	At 1,000 yards.	At 2,000 yards.	At 3,000 yards.	At muzzle.	At 1,000 yards.	At 2,000 yards.	At 3,000 yards.	At muzzle.	At 1,000 yards.	At 2,000 yards.	At 3,000 yards.
8-inch United States muzzle-loading chambered rifle	55	180	1, 639	1, 376	1, 186	1, 042	3, 354	2, 363	1, 755	1, 355	14. 09	9. 93	7. 38	5. 69
9-inch English muzzle-loading service rifle...............	58	250	1, 420	1, 234	1, 091	979	3, 495	2, 639	2, 063	1, 654	11. 61	8. 76	6. 85	5. 49
8-inch United States muzzle-loading service rifle.........	35	180	1, 414	1, 214	1, 063	946	2, 495	1, 839	1, 411	1, 117	10. 49	7. 73	5. 93	4. 69

TABLE No. 6.—*Table of enlargements of 8-inch experimental muzzle-loading chambered rifle, No. 28.*

Inches from muzzle.	Original play of tube, inches.	Original diameter of bore, inches.	Enlargements of bore, including "setting up" of tube after— A total of 13 rounds.	A total of 34 rounds.	A total of 56 rounds.	A total of 76 rounds.	A total of 93 rounds.	A total of 109 rounds.
88	0.002	8.000	0.037	0.043	0.059	0.066	0.067	0.068
87	0.002	8.000	0.035	0.043	0.060	0.066	0.068	0.070
86	0.002	8.000	0.035	0.043	0.058	0.064	0.065	0.068
85	0.003	8.000	0.033	0.041	0.055	0.063	0.063	0.065
84	0.003	8.000	0.032	0.040	0.053	0.059	0.061	0.064
83	0.003	8.000	0.030	0.038	0.050	0.057	0.060	0.064
82	0.002	8.000	0.027	0.035	0.045	0.053	0.057	0.061
81	0.002	8.000	0.025	0.032	0.040	0.047	0.050	0.052
80	0.002	8.000	0.024	0.029	0.038	0.045	0.045	0.051
79	0	8.000	0.026	0.030	0.037	0.046	0.048	0.053
78	0	8.000	0.029	0.033	0.038	0.047	0.049	0.052
77	0.014	8.000	0.030	0.033	0.038	0.047	0.047	0.048
76	0.014	8.001	0.028	0.029	0.035	0.042	0.042	0.043
75	0.014	8.000	0.026	0.028	0.033	0.039	0.039	0.040
74	0.014	8.000	0.025	0.026	0.031	0.037	0.037	0.038
73	0.014	8.000	0.027	0.027	0.031	0.036	0.036	0.038
72	0.014	8.000	0.024	0.024	0.028	0.033	0.033	0.033
71	0.015	8.000	0.023	0.023	0.025	0.029	0.029	0.029
70	0.015	8.000	0.018	0.018	0.020	0.025	0.025	0.025
68	0.008	8.000	0.014	0.014	0.018	0.022	0.022	0.022
66	0.008	8.000	0.015	0.016	0.020	0.024	0.024	0.024
64	0.008	8.000	0.016	0.016	0.020	0.024	0.024	0.024
62	0.009	7.999	0.017	0.017	0.020	0.025	0.025	0.025
60	0.009	7,997	0.012	0.016	0.017	0.021	0.021	0.021
58	0.009	7.999	0.010	0.014	0.019	0.024	0.024	0.024
56	0.009	8.000	0.012	0.013	0.015	0.019	0.019	0.019
54	0.010	8.000	0.010	0.013	0.014	0.018	0.018	0.018
52	0.010	8.000	0.009	0.013	0.013	0.016	0.016	0.016
50	0.010	8.000	0.008	0.010	0.012	0.015	0.015	0.015
48	0.010	8.000	0.005	0.009	0.011	0.015	0.015	0.015
46	0.009	8.000	0.004	0.008	0.009	0.013	0.013	0.013
44	0.009	8.000	0.004	0.007	0.008	0.011	0.012	0.012
42	0.009	8.000	0.003	0.006	0.007	0.009	0.010	0.011
40	0.010	8.000	0.003	0.004	0.006	0.008	0.008	0.009
38	0.010	8.000	0.002	0.003	0.005	0.008	0.008	0.008
36	0.010	8.000	0.003	0.004	0.004	0 007	0.007	0.007
34	0.010	8.000	0.003	0.004	9.004	0.008	0.008	0.008
32	0.010	8.000	0.003	0.004	0.004	0.008	0.008	0.008
30	0.010	8.000	0.003	0.004	0.004	0.006	0.006	0.006
28	0.010	8.000	0.003	0.003	0.003	0.006	0.006	0.006
26	0.010	8.000	0.002	0.003	0.003	0.006	0.006	0.006
24	0.010	8.000	0.002	0.003	0.003	0.006	0.006	0.006
22	0.010	8.000	0.002	0.002	0.003	0.005	0.005	0.005
20	0.010	8.000	0.001	0.002	0.002	0.005	0.005	0.005
18	0.010	8.000	0.001	0.002	0.003	0.005	0.005	0.005
16	0.010	8.000	0.001	0.002	0.002	0.004	0.004	0.004
14	0.010	8.000	0 000	0.002	0.002	0.004	0.004	0.004
12	0.010	8.000	0.000	0.002	0.002	0.004	0.004	0.004
10	0.010	8.000	0.000	0.002	0.002	0.004	0.004	0.004
8	0.009	8.000	0.000	0.002	0.002	0.004	0.004	0.004
6	0.010	8.000	0.000	0.002	0.002	0.005	0.005	0.005
4	0	8.000	0.000	0.003	0.004	0.004	0.004	0.005
2	0	8.000	0.000	0.004	0.004	0.004	0.005	0.005
1	0	8.000	0.000	0.003	0.003	0.004	0.004	0.004

PLATE I.

8 INCH M. L. CHAMBERED RIFLE.



LEGEND

Charge ...	55 lbs
Projectile ...	180 "
Length of Bore (including chamber)	116·98 ins
Diam of Chamber ...	9· "
Length " ...	28·017 "
Velocity (muzzle) ...	1641 feet
Total muzzle energy ...	3357 Ft-tons.
Penetration at muzzle ...	14·09 ins

Scale.

10 8 6 4 2 0 10 20 30 40 50 Inches

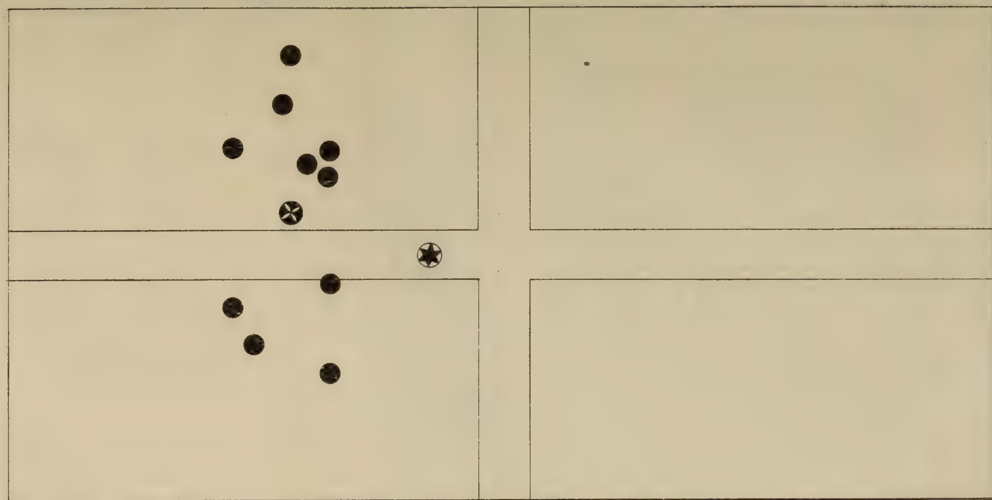
Appendix 9d—1880.

TARGET RECORD OF 8-INCH M. L. CHAMBERED RIFLE No. 28.

At Sandy Hook, N. J., July 15. 1880.

Target One Mile from Gun.

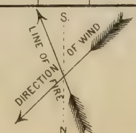
Number of Shots Fired, 10. *Number of Hits in Target, 10.*



Target 20 × 40 Feet. Made of 1" Spruce Boards.

Point aimed at.

Center of Impact.



Mean Vertical Deviation from Center of Impact . . . . *1.26 yards.*

Mean Horizontal Deviation from Center of Impact . . . . *0.44* „

Mean Deviation from Center of Impact . . . . *1.33* „

APPENDIX 9*e*.

REPORT OF THE TRIAL OF THE 3.18-INCH BREECH-LOADING CHAMBERED RIFLE NO. 774 WITH EXPERIMENTAL FIELD-CARRIAGE.

This gun, an alteration of the service 3-inch wrought-iron rifle, together with the experimental iron field-carriage on which it is mounted, will be found fully described with details of construction in the report of the Constructor of Ordnance for the current year. (See Appendix 8*a*.)

The gun and carriage were placed at the disposal of the board on the 26th of May last, accompanied by the record of firing to that date. Since then the small amount of available ammunition has been expended mainly in the test of the breech mechanism of the gun and the strength of the carriage, using powder charges of 2½ and 3 pounds with projectiles weighing 12 pounds. The breech mechanism has worked well, the obturation is complete, and the movement of the block smooth and free.

In the carriage some minor points of weakness were developed and have been corrected. The axle was soon shown to be of inferior material, and has been replaced by one which thus far has shown no disposition to yield. The wheels, originally weighing 235 pounds each, have been replaced by a pair of new construction weighing, each, some 60 pounds less.

Both gun and carriage are now ready for the severer tests decided upon, and with the trial, the subjects of rifling and systems of projectiles adapted to the breech-loading field artillery to be issued to the army, will be investigated practically to such an extent as may be deemed necessary to obtain definite data for further constructions of this caliber now contemplated by the department.

APPENDIX 9*f*.

REPORT ON POWDERS FOR 4½-INCH SIEGE RIFLE.

In the report of the board for 1879 the results of the trial of several experimental powders for this gun were given, the object of the trial being to procure a powder which, with a charge of about 7 pounds and a projectile of 35 pounds in weight, should give a muzzle velocity of about 1,600 feet with pressures not exceeding 40,000 pounds per square inch of the surface of the bore. Of the thirteen varieties tried up to the date of that report, that known as H. D. No. 4 gave the most promising results. Upon resuming the experiments it was decided to try one of the powders of coarser granulation, and consequently slower burning, and for this purpose the variety of Du Pont's manufacture, known as sphero-hexagonal, I. B. A., was selected. Beginning with three-pound charges and gradually increasing to seven, the resulting pressures were so light and the velocities advanced so regularly that the charge was naturally increased to 8 pounds. By reference to the appended table it will be seen that this charge gave an average velocity of 1,542 with a corresponding pressure of 26,166 pounds per square inch of bore. With this satisfactory record the board recommended the adoption of this powder for service with 4½-inch rifle, and this recommendation received the approval of the department in April last. Upon the completion of an order for the powder for issue, based upon this recommendation, the board was furnished with samples for further test. The results gave an average pressure of 32,500 pounds with a corresponding increase in velocity from 1,542 to about 1,575 feet. The greater pressure (entirely within limits of safety) is doubtless due to a great extent to the newness of the sample, and indicates for stored powder a velocity of 1,550 feet with a pressure of about 30,000 pounds as that to be depended on for the powder now adopted as the standard for this rifle.

Experiments to ascertain proper kind and charge of powder for use in 4½-inch siege rifle.

Number of round.	Date.	Powder. Kind.	Powder. Density.	Powder. Granulation.	Powder. Weight of charge.	Projectile. Kind.	Projectile. Weight.	Elevation.	Instrumental velocity at 80 feet.	Pressure per square inch of bore.
	1880.				*Lbs.*		*Lbs.*	*Degrees.*	*Feet.*	*Lbs.*
245	April 15	Du Pont's sphero-hexagonal, I. B. A.	1,728	123	3	Absterdam shell filled with sand and lead.	25	−¼	764	6,000
246	April 15		1,728	123	3¼		35	−¼	796	5,500
247	April 15		1,728	123	4		35	−¼	1,016	9,000
248	April 15		1,728	123	5		35	−¼	1,210	14,000
249	April 15		1,728	123	6		35	−¼	1,337	19,500
250	April 15		1,728	123	7		35	−¼	1,424	21,500
251	April 15		1,728	123	8		35	−¼	1,530	26,000
252	April 15		1,728	123	8		35	−¼	1,536	26,500
253	April 15		1,728	123	8		35	−¼	1,525	26,000
254	June 24	Du Pont's sphero-hexagonal, I. B. B.	1,728	123	7		35	−¼	1,476	27,500
255	June 24		1,728	123	7½		35	−¼	1,539	30,000
256	June 24		1,728	123	8		35	−¼	1,546	35,500
277	July 9		1,728	123	8		35	0	1,583	34,000
278	July 9		1,728	123	8		35	0	1,567	28,000

REMARKS.

Mean average muzzle velocity, using 8 pounds I. B. A. powder, 1,542 feet, with corresponding pressure of 26,166 pounds.

Mean average muzzle velocity, using 8 pounds I. B. B. powder, 1,575 feet, with corresponding pressure of 32,500 pounds.

APPENDIX 10.

REPORT OF THE PRINCIPAL OPERATIONS AT ROCK ISLAND ARSENAL DURING THE FISCAL YEAR ENDED JUNE 30, 1880.

MAJ. D. W. FLAGLER, ORDNANCE DEPARTMENT, COMMANDING.

(Four plates.)

SHOP G,

An iron working and finishing shop for the arsenal.

The work done on this shop during the fiscal year is the following:

Masonry.

The stone for the second and third stories has been all cut and these two stories built entire, thus completing the walls of the building. Only about two-thirds of the stone for these two stories had to be purchased, the other one-third being on hand at the beginning of the year.

Iron-work.

The iron beams for the second floor have been drilled and fitted, the caps and bases for both floors and the iron columns for the second story have been manufactured in the arsenal shops, and all this iron-work has been put up and finished.

The iron bar for the roof frame has been all made from old scrap in the new rolling mill.

Wood-work.

The door frames and doors, and window sash and window frames, have all been manufactured during the year, and the glass all purchased and the sash all glazed. These are all ready for putting in as soon as the roof is on the building.

The window hangings, door hinges, bolts, knobs, and other house hardware for the shop, have all been made in the arsenal shops during the year.

Attention is invited to a general increase in wages for nearly all kinds of labor, and a great increase in the price of iron that has occurred during the year. This increase has amounted to about $8,000 in all for the work done on this building, and has diminished the amount of work done on the building accordingly. I expected with the appropriation to purchase nearly one-half of the beams for the roof frame, and make a portion of the roof frame during the winter and have it ready to put up as soon as the walls were completed. But, for the reasons stated, this could not be done, and the delay and loss embarrass considerably the work of completing the building during the present fiscal year. To complete the building during this year it is absolutely necessary that the roof should be manufactured and put on, and all the fire-proof brick

arches for the floors put in, before frost this fall. There are about three acres of these fire-proof arches. This necessitates the purchase of the iron beams in great haste, and the manufacture of the iron roof frame in the arsenal shops in great haste also, during the months of July, August, and September of the present fiscal year, while other work is pushing.

This is mentioned here simply to illustrate the very serious difficulties, and sometimes losses also, incident to a compliance with the act of Congress of July 12, 1870, requiring the covering into the Treasury of unexpended balances of appropriations at the close of the fiscal year.

If the work of completing the building could be deferred from June 30 to September 30, 1881, three months only, then the work of manufacturing the roof frame could be deferred till winter, when there is nothing else to do, and there would be left time in the spring to put on the roof, put in the fire-proof arches in good weather, and finish the building after that.

The Grafton stone, of which the walls of shop G are built, is more durable than any other that has been used at the arsenal, and although it matches the other closely in color, it is finer in appearance, and makes this very much the handsomest building at the arsenal.

SHOP I,

A wood-working and leather-working shop for the arsenal.

The work done on this shop during the fiscal year is as follows:

Stone-work.

The walls of the first story above the basement have been built entire, and nearly all the stone for the second story has been purchased, and part of it has been cut.

Iron work.

The beams for one-half of the second floor have been purchased, drilled, and fitted, and the columns, caps, bases, and other iron-work for the same have been manufactured in the arsenal shops, and this iron-work put up.

Attention is invited to the fact that the last annual estimate sent to the Chief of Ordnance includes an estimate for sufficient funds for finishing this building. This estimate is ample for completing the building, unless unexpected and very unusual changes in the price of materials should occur.

This estimate, added to the amounts heretofore appropriated for and expended on the building, makes a total of $333,500, which is $270,000 less than the cost of each of the first two shops built at the arsenal. The buildings are precisely the same in dimensions and construction. The two shops referred to, which were built first, are B and C, and they were completed in 1872. Probably $125,000 nearly of this money is due to natural changes in the prices of labor and material. The remainder is due to changes in the method of doing the work, and largely to the production in the arsenal shops of articles required, and of doing the work by government employés instead of procuring the same by purchase and contract.

SHOP II,

An iron-finishing shop for the armory.

The work done on this shop during the fiscal year is as follows:

Masonry.

About one-third of the foundations for the main walls of the building have been put in, thus completing the foundations of the walls, and the foundations for the 76 stone piers which support the floors have been put in. (A description of this work will be given further on.)

The walls of the basement story have been completed, all the stone piers have been built, and the iron bases for supporting the columns of the next story have been made and put on them, and about four-fifths of the stone required for the next story has been purchased and cut and is now ready for setting. This stone has been furnished under contract by Messrs. Sanger & Moody, from their Joliet quarries, the same quarries that have furnished most of the other Joliet stone used at the arsenal. It has been furnished with great promptness, and is the best stone, both in quality and dimensions, that has come from these quarries.

The whole amount of masonry foundations put in for this building during the year was 4,292 cubic yards. The amount put in during the previous year was 4,647 cubic yards, making the total amount of foundations for this building 8,939 cubic yards, which is about 1,400 yards more than the walls of the building will contain.

In my annual report for the fiscal year ending June 30, 1879, a full description was given of the foundations for this building that were put in during that year, and geological charts on Plate I, which accompanied that report, exhibited the strata passed through in the excavations for foundations and the bottom on which the foundations rest.

Plate I, transmitted herewith, gives the same information in regard to the foundations put in during the year ending June 30, 1880, and as the preservation of this information may become important to those who are to come after us, the drawings of the foundations put in the previous year are put in on this sheet also, so that this sheet shows all the foundations for the walls of the whole building.

The character of the work done and the difficulties encountered are precisely the same as were described in my annual report for the previous year, and therefore no further description of the work is given here.

An additional drawing (Fig. 5) is shown on Plate I to describe better the bottom of the foundations in the difficult pocket encountered in the previous year. A portion of the information used in making this drawing was obtained in making excavations for an adjacent pier, which work and its connection with the old foundations are described further on.

On Plate II, Fig. 2, is shown the masonry foundations of one pier, the strata passed through in excavating for the same, and the bottom on which the foundations rest. Fig. 1 on the same sheet is a plan of the building on which all the piers are numbered consecutively from 1 to 76, and on the same plate a table gives the depth of excavation for each pier foundation, the dimensions of each foundation, and the character of the bottom on which it rests. It is believed that this gives all the information that can ever be required in regard to these foundations. The character of the foundations and the method of putting them in was the same as has been described in previous reports and is not repeated here.

The trouble with water was more serious in the excavation for these pier foundations than in excavating for the walls. The latter being long trenches, steam-pumps of large power could be placed at low places at long intervals and made to drain long stretches of from 100 to 200 feet and discharge the water through pipes and troughs into the sewers. The excavations for the piers being separate excavations, the expense of setting a steam-pump for each would have been too great. The water had to be pumped with numerous hand-pumps, and getting rid of the water economically from so many pits, over so large an area, was exceedingly difficult. After excavating it was necessary to operate the pumps until the masonry was raised above the water-level.

As shown by the drawings, all these excavations passed through beds of sand and gravel. The natural drainage of these beds was stopped some years ago by a heavy fill of clay and rock along the line of North avenue, so that all the rainfall on an area of about 7 acres found its way into these excavations and had to be pumped.

PIER 26.

The drawings on Plate III exhibit the excavations for and foundations of pier No. 26. This work was more difficult than any foundation work I have had to do at the arsenal. As shown on the drawing (Fig. 5) this excavation is alongside the deep excavation made for the main wall in the previous year, and is 7 feet deeper, making a total depth of 74 feet. This excavation furnished the information for the additional drawing of the old foundations given on Plate I.

It should be stated here that this costly excavation might have been avoided had the only object been to provide a foundation for a pier to support the floors and columns. The total weight to be sustained by the pier is 138 tons. It was practicable to substitute an iron column for the pier, and then support this column by truss rods hung from the main wall and one of the adjoining piers, having first strengthened the main wall and adjoining pier for bearing the increased weight. This was objectionable because it would have been a blot upon the building, insomuch as it would have been a make-shift and have shown a failure to procure a foundation.

A study of the information gained in the adjacent excavation made in the previous year led me to believe that I would find a good rock foundation for the pier at a depth of about 26 feet; also, preliminary soundings struck this rock.

When uncovered, however, it was found to be only a soft projecting point of the ledge found in the previous year. It was then drilled, split off, and taken out, and renewed soundings in the soft clay below again gave apparently good rock about 11 feet deeper. This, when reached, was found to be only a large loose mass of rock, bedded in the loose, soft clay, and had to be taken out.*

* These great irregular crevices and pockets in the rock underlying the island, which have given so much trouble in procuring foundations in some cases, have been partially described in previous reports. First, these crevices and pockets appear to have been formed by a breaking up of the rock and its wearing away with water. At a subsequent period they have been filled up with deposits of clay and drift (sand and gravel) mixed with small fragments and sometimes large masses of rock, worn and broken from the adjacent ledges. Sometimes foreign bowlders, brought from a distance, have been found at great depths. (See K and L, Fig. 5, Sheet I.)

In many places the irregular form of the crevices and pockets, projecting points of rock, and loose masses of rock wedged in between solid beds appear to have kept the weight of superincumbent drift from the lower beds, and the latter are sometimes a loose filling of clay, mixed with stones, saturated with water, and sometimes so soft

Soundings made in this way, from place to place, indicated that a good rock foundation could be obtained until the excavation had reached a depth of 58 feet. The soundings at this point showed that good rock foundations could not be obtained at all within a reasonable depth. I would then have filled up the hole, abandoned putting in a pier, and have substituted therefor the iron column and truss described a few pages back, had not the careful soundings made at this point led me to fear that the foundations of the adjacent main wall of the building, put in the previous year, were not as secure as I had supposed. (For convenience I will call these the old foundations.) I then determined to go down at least to the bottom of the old foundations, and, as far as possible, do whatever might be found needful to secure and strengthen them. This was done.

It is not easy to give a full and clear description of all that was found out and done in regard to these foundations, and only a partial description will be attempted.

Fig 5, Plate I, is a plat of the bottom of the old foundation. Rock R is strong limestone. Rock M M is soft and brittle, mixed clay, sand, and lime-rock that appears to be a later deposit than the other rock. It is a good solid foundation for supporting weight, but not for resisting a tendency to slide. K is a bowlder, apparently granite, firmly bedded in it. L is another bowlder, bedded in the same rock at one end, and apparently fastened into rock R at the other. S is a crevice, and could not be sounded to a considerable depth because of its irregular rock sides. The surface of rock R declines toward L at an angle of about 10°. The crevice S could not be cleaned out thoroughly without taking up rock R. The condition of the sheathing of the excavation, the season of the year, the flow of water, and many other difficulties made it impracticable to do this or go deeper with the excavation. The crevice S was cleaned out as deep as possible, filled with concrete, and the foundation built on the bottom as shown on the plat and described above. I deemed the foundation secure. For description of masonry, see drawings on Plate I and report for fiscal year ending June 30, 1879.

The only defect in the foundation was crevice S, or rather the lack of certain knowledge in regard to its extent and character, and a barely possible tendency of the foundation to slide toward L.

The soundings made at a depth of 58 feet in the adjacent pier excavation, which were mentioned a few pages back, led me to suppose that crevice S enlarged into a wide pocket beyond the point L, and that therefore the foundation was not as secure at that place as was supposed.

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that men and tools might sink suddenly into them out of sight. In some cases small caves or empty pockets have been found. Large loose fragments of rock weighing as much as 40 tons have been found bedded in the loose clay. These were sometimes insecure, could not be built upon, and care was required to avoid mistaking them for solid rock or for fragments resting on solid rock. If bedded in the soft clay, they had apparently settled until a position of equilibrium was reached. If weight were added by building on them, their equilibrium would be disturbed and they would settle, surely though slowly. Sometimes these masses have been passed in sinking excavations, and the water running through the sheathing below, bringing earth with it, would gradually undermine the stone, cause it to settle against the sheathing, and slowly distort, crush, and break the sheathing, no matter how strong. This break in the rock-bed of the island, forming a sort of underground ravine and probable ancient water way in the rock, runs diagonally from southeast to northwest across the site of the shops, so as to include about two-thirds of the site of shop I, and nearly all of shop G, in the arsenal row, and nearly all of shop H, about one-half of shop F, and a little corner of shop D, in the armory row. On both sides of this ravine the rock-bed is solid and good, and the most perfect foundations were obtained without trouble.

No trouble is anticipated in procuring perfect rock foundations for shop K, the only shop whose foundations are not now completed.

When the pier excavation had passed below the old wall foundation the above supposition was confirmed, and I also found by soundings that the crevice S extended and enlarged under rock R. These soundings showed, however, that the portion of rock R which is under the dotted shading lines rested on solid rock below.

Fig 1, Plate III, shows in plan the relative positions of the pier excavations and the old wall foundation. *f f f f* is the bottom of the old wall foundation; *g g g g* is the bottom of the new pier foundation. The latter is 7 feet below the former. In going down below the old foundation, bowlder L was loosened and removed, and quantities of loose rock and clay were taken out of crevice S from underneath the old foundation. From this point the lateral soundings were made into crevice S and under rock R. The information obtained is shown in the cross-sections in Fig 2, Plate III.

From the bottom of the pier excavation *g g g g* deep vertical soundings were made. These gave no probability of finding a good rock foundation. The soundings were made with steel-pointed jointed iron bars and jointed drills. Loose masses of rock in the soft clay interfered with the soundings. The lateness of the season (November 4), the condition of the sheathing above, and the inflow of water made a deeper excavation impracticable, and the soundings indicated that it would be useless. I then determined to put in piles.

The loose, saturated clay is a poor material for sustaining piles. The fragments of rock bedded in it interfered with driving them. To overcome the latter difficulty the bottom of the piles were shod with heavy, sharp-pointed iron shoes, to split, break, or push the rock aside. Twenty-six 12-inch square piles were driven to depths varying from 14 to 17 feet. Their positions are shown in Fig. 3.

It should be remembered that the excavation, in the bottom of which the piles were driven, was only 10 by 12 feet, and was 74 feet deep. The space was filled up with a network of sheathing timbers, irregularly placed to meet excessive pressure at different points. A steam pump was operated at the bottom of it, and space had to be provided for steam and water pipes and plank tubes through which material was hoisted out.

In driving the piles a timber tube was used to guide the drop among the sheathing timbers and prevent accidents to workmen, the pump, &c. This tube is shown in Fig. 5. It is 30 feet long.

The piles were lowered *through* the tube; then the *drop* was lowered down to rest on the pile, the tripping apparatus inserted in the top of the tube, and the driving was done by a steam-engine, in the ordinary way. The driving had sometimes to be done with the tube inclined until the top was $2\frac{3}{4}$ feet out of plumb. It worked well with this amount of inclination.

The drop weighed 900 pounds, and the driving was continued as long as a drop of 27 feet imparted any motion to the pile.

Before putting in the piles the loose rock and mud was cleaned from under rock R and from crevice S, under the old foundation, as far as practicable, with long hoes and other devices, and the space was then refilled with well-rammed concrete, while a special effort was being made with the pump to keep down the water. The adjacent piles were then driven with an inclination under the old foundation so as to crowd the bed of concrete and loose fragments of rock more firmly into the crevice.

After the pile driving was finished, the tops of the piles were sawed off evenly; the interstices between them were cleaned out to a depth of 4 feet, and then filled with concrete well rammed with iron tamping

bars. On this a course of footing stones 12 inches thick was laid. On these ordinary masonry was laid, with occasional courses of footing stones, till the surface of the ground was reached. (See Fig. 4, Plate III.) Eagle Portland cement was used for all this masonry. The work lasted till heavy frosts set in. Hot water was used at times for mixing the mortar and keeping it warm till it was lowered below frost in the pit. The masonry was brought up to within 7 feet of the surface. Then the hole was filled with clay till warm weather in the spring, when it was taken out and the pier completed. The excavation was commenced August 1 and completed November 4. The pile driving was finished November 16, and the masonry work December 4.

OPINION.

It is not probable that these foundations will ever settle enough to give serious trouble. They can only settle a little, and very slowly. They cannot give way so as to endanger the building.

The pier foundation is more likely to settle than the other. If this should happen, it can do no harm. It would only cause a slight settling of the shop floor over the pier, and this can be easily remedied by wedging up the iron base on the masonry pier.

The pier foundation buttresses and strengthens the wall foundation, and its weight secures the latter still more by pressure against whatever underlies the wall foundation. For this reason a settlement of the pier foundation would probably benefit the wall foundation.

The worst that can ever happen would be a sufficient settling of the wall foundation to cause a serious crack in the wall of the building. If this ever occurs, the only remedy will be to take down and rebuild a portion of the wall *on the present foundation.* This should not be done until the settling was finished. It is certain that the foundations now in are the best that could be built, and nothing would be gained by attempting to improve or strengthen them.

ROLLING MILL.

As the manufacture of bar iron from scrap in this mill is an experiment, the following report of the work done in this shop during the year is made:

In my last annual report a report was made of some work done between June 15 and July 17, 1879; therefore this work is not reported here.

From January 21 to 29, 1880, the furnace and steam hammer were run, and 91,071 pounds of hammered blooms were made for making the high grade of bar iron required for roof rods of shop G. These blooms were subsequently rolled, reheated, and rerolled once, to make the finished bar required for the roof rods. This gave a very tough, fibrous iron that works and welds well in the forging shop. Numerous tests of samples gave an ultimate tenacity of from 51,000 to 54,000 pounds, and a minimum elastic limit of 30,000. The latter is higher than anything I have known, and is the important quality for this iron. I believe the iron is better than that which has been used in the other roofs.

April 8 to 13 and May 12 to 14 the mill was run in rolling the above iron, making more blooms and rolling them, and in rolling common iron directly from scrap piles without blooming. The total amount of bar made was 130,000 pounds. Of this 77,000 pounds were for roof rods, and the remainder common bar for general use and railroad rail for tramways and derrick tracks. The total expenditure was

$2,012.53, or $1.55 cents per pound. The cost of the iron at prices which have held during the year would have been about $4,600. The cost of running the large boilers and engine for operating the steam hammer and fan for blooming only, when the mill was not running, has made the iron cost more than it should. No more blooms should be made until a boiler can be put over the rolling mill heating furnace to furnish steam for these purposes.

I also hope to procure regular arsenal workmen, who can perform the duties of furnace man and hammerer, and avoid the extraordinary wages which had to be paid last year. This should reduce the cost of blooming to about $8 per ton, and the cost of making bar iron from scrap to 1 cent per pound.

IMPROVEMENT OF GROUNDS, PRESERVATION OF BUILDINGS, BRIDGES, &C.

During the fiscal year the exterior woodwork of shop B and of the three sets of subaltern officers' quarters have been repainted for preservation; a new floor has been put on the wagon bridge to Moline; the oak lumber for a new floor to the wagon bridge to Rock Island has been purchased and stacked for seasoning; Fort Armstrong avenue and the causway leading to the Rock Island wagon bridge have been macadamized; the grounds reserved as sites for officers' quarters, east of those now built, have been graded, and hedges and trees planted and fences built; a portion of the grounds along the line of East avenue has been graded, gutters built, and trees planted, and the grounds in the vicinity of the pulley house, at the water-power dam, have been graded, a fence built around them, grass, trees, and ornamental shrubs planted, walks and roads built, and a rough rock ornamental fountain put in.

Five cast-iron gates have been put into the water-power dams to replace the wooden ones, which have warped and broken. On Plate IV, transmitted herewith, are drawings of these gates. When not bolted together for use in front of a water wheel which is in use, these gates are so arranged that any of the upper sections can be raised without disturbing the lower ones, for drawing off bark, chips, and drift from the pool. One man can raise and lower the gates with the pressure of the head of water against them. The wooden gates were not designed to be and could not be moved with the pressure of the head of water against them. They are now generally so much warped that they can not be moved at all without breaking them.

The combined action of the water and pressure on one side, and the sun on the other, is gradually destroying the wooden gates, and the whole 76 of them in the two dams should be replaced by the iron ones, gradually, as there are funds therefor.

HIGH WATER OF 1880.

The record of stages of water of the Mississippi River shows that on June 26, 1880, the stage of water was 18.40 feet. From the best information I can procure, and I deem the information reliable, this stage of water was 1.08 feet higher than the high water of 1870, and higher than any stage of water that has ever occurred at this place of which there is any certain record.

The water flowed over the water-power dams throughout their entire length, and it was 11 inches deep on the lower dam. No damage of importance was done to any part of the water-power. Some rock was washed from the stone dike at the east end of the lower dam, and a portion of the small dam at Benham's Island was washed away.

There was some danger that the west end of the earth dike on the Illinois shore and the earth dike just above the pulley-house, on the island shore might be washed away. Had this occurred much damage would have been done to the bridges below and to the city of Rock Island. Both the dikes became saturated with water and leaked badly. A force of men and teams was engaged ten days and nights in strengthening them, and they are now being put in secure condition.

Nearly one-third the island was under water for about ten days, and the beautiful blue-grass on portions of the island was destroyed.

It is important to note here that a serious error was made in 1872 in transferring the water-gauge from the old Chicago, Rock Island, and Pacific Railroad bridge to the new government bridge (the Rock Island bridge).

All records of stages of water at this place prior to 1872 are the records of the old gauge mentioned above. All records kept since 1872 are those of the new gauge on the Rock Island bridge. These records are important in many ways, and particularly in determining the effect on stages of water of cutting away forests on the upper tributaries of the river.

Some observations made on low-water by the United States Engineer Corps, a few years ago, indicated that the new gauge had been set .35 of a foot too low. I find now that the error is more than this.

The record of the high-water of 1870 (April 24), on the old gauge, is 16.65 feet. The record of the new gauge, June 26, 1880, is 18.40 feet, and the difference is 1.75 foot. The observations and records of high-water mark at both times in the vicinity of the two bridges are accurate and reliable, and show, as stated above, that the high-water of 1880 was only 1.08 foot higher than that of 1870. In this way it is determined that the new gauge is set .67 of a foot too low, and I have adopted this error in connecting the old and new records.

The following statement is appended to this report, viz:

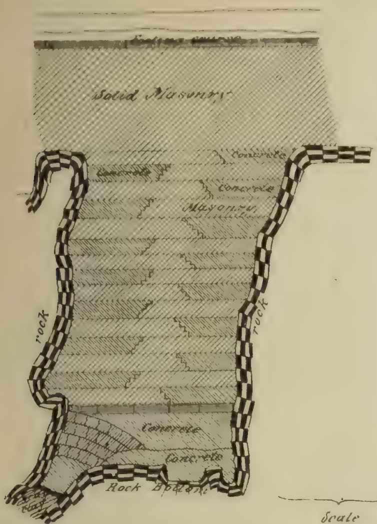
APPENDIX A.

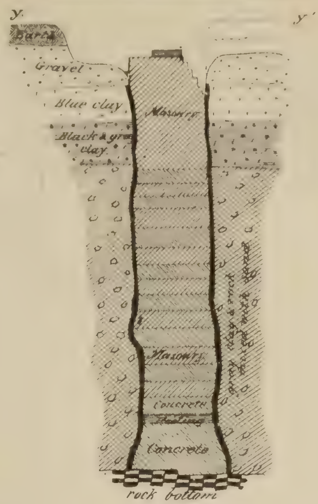
Statement of the number of persons and teams that have crossed the Rock Island (government) bridge during the year.

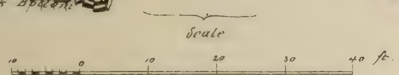
PASSING NORTH.	
Engines with trains	5,236
Engines without trains	397
Total engines	5,633
Passenger cars	7,463
Freight cars	108,876
Foot passengers	256,355
Teams	184,647
Steamboats	1,374
Barges	387
PASSING SOUTH.	
Engines with trains	5,394
Engines without trains	166
Total engines	5,560
Passenger cars	7,537
Freight cars	109,092
Foot passengers	257,319
Teams	174,419
Steamboats	1,385
Barges	350
Rafts	685

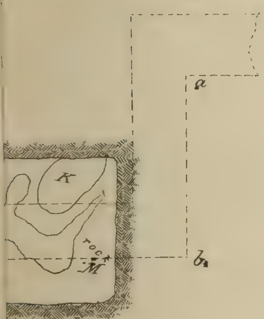
Fig 3.

Vertical Section at y. y' (Fig 4)









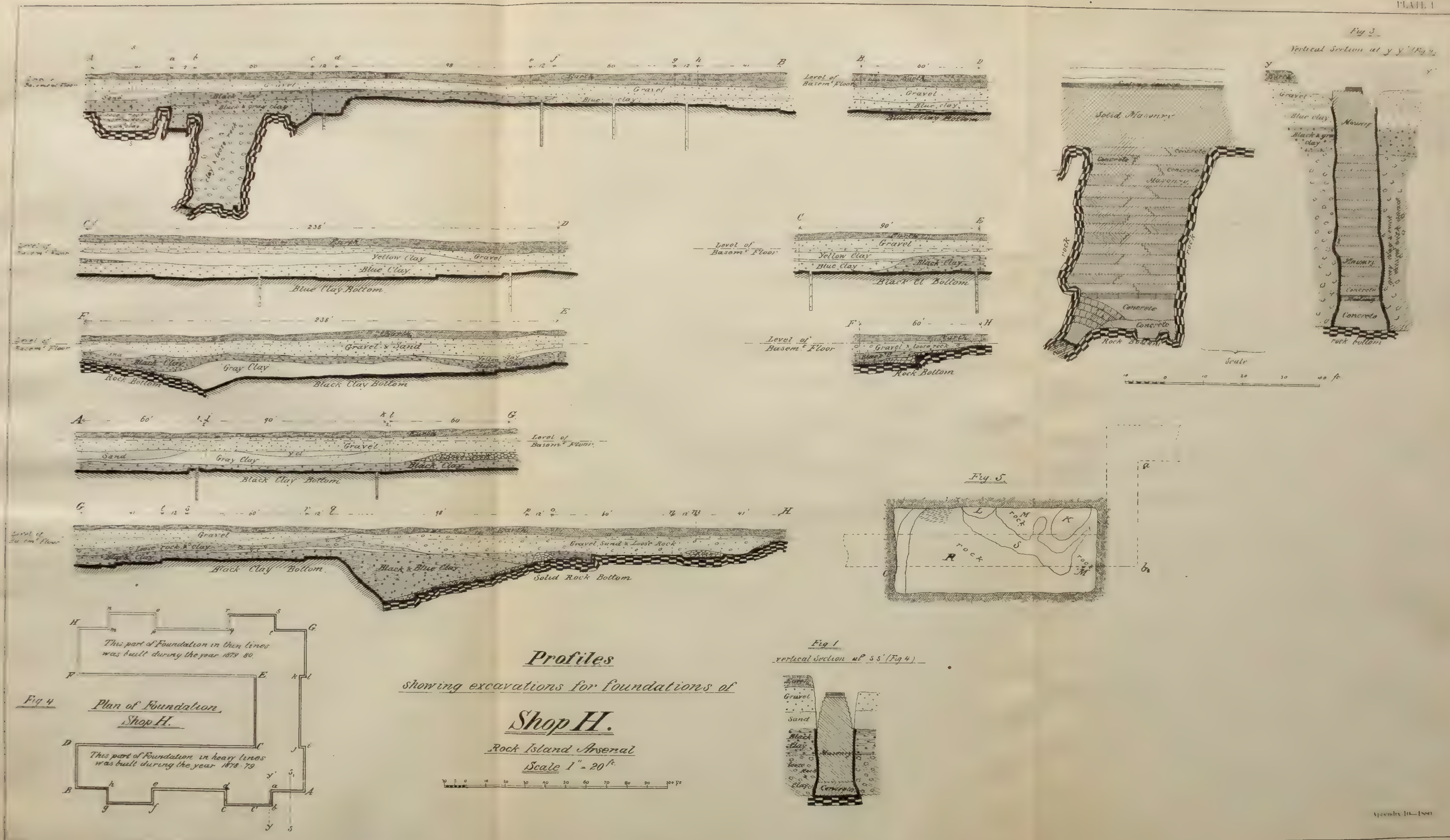


PLATE I
Fig 3.
Vertical Section at y y' (Fig 4)
Level of Basem't Floor
Earth
Gravel
Black clay
Blue & Gray Clay
Blue clay
Black Clay Bottom
Yellow Clay
Blue Clay Bottom
Black Cl. Bottom
Gravel & Sand
Gray Clay
Rock Bottom
Gravel & loose rock
Sand
Black Clay Bottom
Gravel, Sand & Loose Rock
Black & Blue Clay
Solid Rock Bottom
Solid Masonry
Concrete
Masonry
Rock Bottom
rock bottom
Scale
Fig. 5
rock
Fig 1
Vertical Section at S S' (Fig 4)
Fig 4
Plan of Foundation
Shop H.
This part of Foundation in thin lines was built during the year 1879-80.
This part of Foundation in heavy lines was built during the year 1878-79.
Profiles
showing excavations for foundations of
Shop H.
Rock Island Arsenal
Scale 1" = 20 ft.
Appendix 10—1880

of Materials excavated.				Total depth of Excavation from Basemt. floor.	Nature of Bottom of Foundation.	Dimensions of Bottom of Foundation.
2'	Bl Cl. 3'			6 feet deep	Bl. Cl.	8½ feet square
Cl 4½'				7½ " "	Blk. Cl.	7½ " "
" 4½'				7½ " "	" "	7½ " "
" 4½'				7½ " "	" "	8 " "
" 3'				7' " "	" "	7½ " "
" 3'				8 " "	" "	7½ " "
d ½'	Blk. Cl. 4'			8 " "	" "	9 " "
Cl. 3'				6½ " "	" "	7' × 7½'
" 4'				7 " "	" "	7½ ft sq.
" 5'				8 " "	" "	9' " "
" 4'				7 " "	" "	8 " "
" 7'				8 " "	" "	9 " "
d ½'	Blk. Cl. 4'			7½ " "	" "	8 " "
2'	" " 4'			10 " "	" "	8 " "
Cl. 4'				8' " "	" "	7½ " "
d. 1'	sand & R 2'.	Black Cl. 3'.	"	9½ " "	" "	8 " "
& R. 3½'	Blk. Cl. 4.'			9 " "	" "	7½ " "
Cl. 2'	•			10 " "	" "	8 " "
" 3'				11 " "	" "	8 " "
& R 3'	sand rock with iron ½'	Bl. Cl 2.'		10½ " "	Bl. Cl.	8' " "
Cl. 5'				11 " "	Blk. Cl.	8' " "
& R 3'	sand rock with iron ½'	Gr. Cl. 2.'		10½ " "	Gr. Cl	8 " "
Cl. 2'				8 " "	Blk. Cl.	7½ " "
d 1'	Grvl & R 5'			9 " "	Rock	7 " "
1'	C. Grvl & R. 3'	Gr Cl. 3'.		11 " "	Gr. Cl.	9 " "
Cl. 2'				8 " "	Rock	7' " "
d 1'	Grvl & R. 5			9 " "	"	7 " "
& R. 6'				8½ " "	"	8 " "
d 1'	Grvl & loose R 4'			8 " "	"	7 " "
d 2'	C Grvl 3'			8½ " "	"	8 " "
3	" " 1'			8 " "	"	7' × 9'

n Table.

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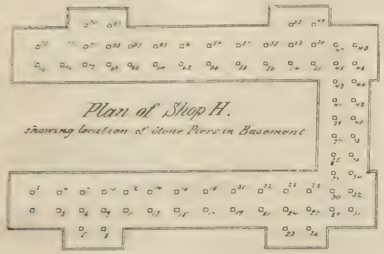
y.

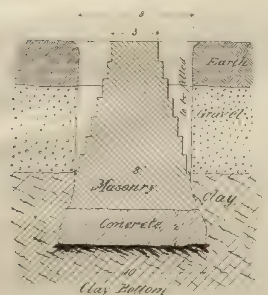
Pier Foundations. Shop H. Rock Island Arsenal.

Fig. 1



Plan of Shop H.
showing location of stone Piers in Basement

Fig. 2



Note

The general character of Foundations for Piers in this shop is represented in the above Fig 2.
The excavation, being widened at the bottom about one foot all around, is first filled up with concrete to a depth of 2 feet, then solid Masonry to the upper surface of the clay stratum and then tapering gradually with solid Masonry to the required level, forming a surface at the top of 3 feet (minimum) square.

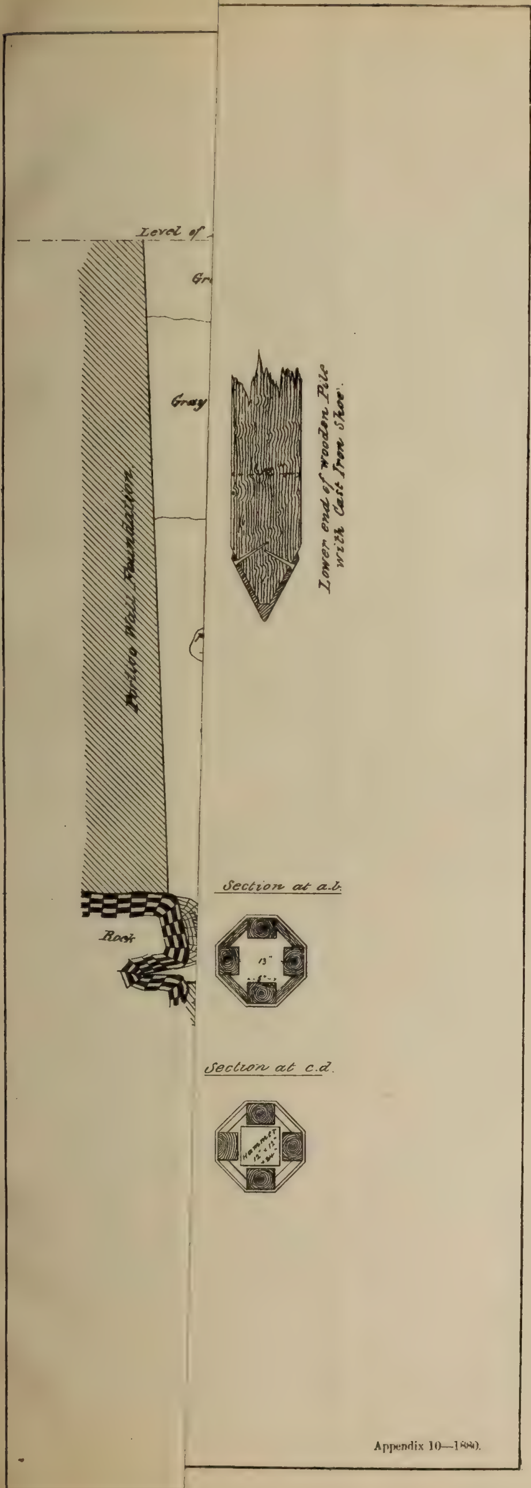
Nº of Pier	Depths of Materials excavated					Total depth of Excavation from Basem't Floor	Nature of Bottom of Foundation	Dimensions of Bottom of Foundation
1	Earth 2'	Sand 2'	Grvl 4'	Blk Cl 5'		13 feet	Blk Cl	10' square
2	" 2'	Gravel 7'	Blk Cl 3'			12 "	"	9' "
3	" 3½'	" 7'	" 3½'			14 "	"	8½' "
4	" 3'	9'	" 3'			15 "		10' "
5	" 6'	" 5'	" 4'			15 "	"	11' "
6	" 3'	" 6'	" 5'			14 "	"	8½' × 9'
7	2'	Sand 1½'	Grvl 6'	Blk Cl 3'		12½		10' square
8	" 3½'	Gravel 6'	Blk Cl 5'			14½ "	"	9' "
9	" 3'	" 6½'	" 5'			14½ "	"	8' × 9'
10	" 3'	Sand 1½'	Grvl 7'	Blk Cl 4'		15½ "		10' square
11	" 3'	Gravel 6'	Bl Cl 3'			12 "	Bl Cl	7½ × 8'
12	3'	Sand 1'	Grvl 7½'	Bl Cl 4'		15½ "	"	10' square
13	" 1½'	Gravel 6	Bl Cl 3½'			11 "	"	7' "
14	" 3½'	Sand ½'	Grvl 7'	Bl Cl 5'		16 "	"	9' "
15	" 2'	Gravel 6'	Bl Cl 3'			11 "	"	7' × 7½'
16	" 3'	7'	" 3			13 "	"	10' square
17	" 1'	" 5'	Sand 2'	Bl Cl 4'		12' "	"	7½' "
18	" 4'	" 6'	Bl Cl 5			15 "	"	9' "
19	" 1'	" 6'	Sand 2½'	Gr Cl 3'		12½ "	Gr Cl	8' "
20	" 3½'	2'	Bl Cl 6'			11½ "	Bl Cl	9' "
21	" 1'	" 5½'	Sand 1'	Gr Cl 3'		10½ "	Gr Cl	8' "
22	4'	" 6'	Bl Cl 5½'			15½ "	Bl Cl	9' "
23	Gravel 7'	Gray Clay 17'				24' "	Rock	11'
24	" 5	Sand 1½'	Y. Cl 1'	Gr Cl 4'		11½ "	Gr. Cl.	8½' "
25	Earth 4'	Gravel 6'	Gray Cl 5'			15 "	" "	10' "
26	Gravel 7'	Gr Cl 18'	Gr Cl & R 37'			see Plate III.		
27	5½'	Sand 1'	Gr Cl 6'			12½ "	Gr. Cl.	9½' "
28	Earth 3'	Gravel 3'	Sand ½'	Gray Cl 6'		12½ "	" "	10' "
29	Gravel 6'	Gr Cl 6'				12 "	" "	9½' "
30	" 4'	Y Cl & R 1'	Gr & Y Cl 4'			9 "	" "	9' "
31	" 7'	Gr Cl 5'				12' "	" "	10' "
32	Grvl 5'	Bl. Cl. 4'				9' "	Bl Cl.	8' "
33	Earth 1½'	Grvl 2½'	Sand 1'	loose R 1'	Bl Cl 4½'	10½ "	" "	8' "
34	Grvl 5'	Y. Cl 1'	Gr Cl 6'			12 "	Gr Cl	8' "
35	" 3'	loose R & sand 2'	Bl Cl 6'			11 "	Bl Cl.	8' "
36	" 3'	Sand 1'	Grvl 1'	Y. Cl 2'	Gr. Cl 5'	12 "	Gr. Cl	8½' "
37	Earth 1½'	Grvl 1½'	Bl & Y. Cl 6½'	" " 6½'		9½ "	Bl Cl	8½' "
38	Grvl 4'	Y Cl 2'	Gr Cl 5'			11 "	Gr Cl	8½' "
39	1'	Earth 1'	Grvl 1'	Bl Cl 8'		11 "	Bl Cl.	8' "
40	" 4'	Sand 1'	Y Cl 1½'	Gr Cl 5		11½ "	Gr Cl	8½' "
41	" 4'	Bl. Cl 6				10 "	Bl Cl	8' "
42	" 2	Y. Cl 1½'	Gr Cl 5'			8½ "	Gr Cl	8' "
43	Coarse Grvl 5'	Sand ½'	Blk Cl 5'			10½ "	Blk Cl	8' "
44	Gravl 1'	Y. Cl 1'	Gr Cl 12'			14 "	Gr Cl	9' × 8½'
45	3'	Blk Cl 4'				7 "	Blk Cl	8' square

Nº of Pier	Depths of Materials excavated					Total depth of Excavation from Base-floor	Nature of Bottom of Foundation	Dimensions of Bottom of Foundation
46	Earth 1'	Grvl 2'	Bl Cl. 3'			6 feet deep	Bl Cl	8½ feet square
47	Grvl 3'	Blk Cl 4½'				7½ " "	Blk. Cl.	7½ "
48	" 3	" " 4½'				7½ " "		7½ "
49	Coarse Grvl 3'	" 4½'				7½ "	"	8 "
50	Grvl 4	" " 3'				7' "	" "	7½ "
51	" 5'	" " 3'				8 " "	" "	7½ "
52	" 3½'	Sand ½'	Blk Cl 4'			8 " "	" "	9 " "
53	" 3½'	Blk Cl. 3'				6½ " "	" "	7' × 7½'
54	" 3'	" " 4'				7 " "	" "	7½ ft sq
55	" 3'	" " 5'				8 " "	" "	9' " "
56	Grvl & R 3'	" " 4'				7 " "	"	8 " "
57	Grvl. 1'	" " 7'				8 " "	" "	9 " "
58	" 3'	Sand ½'	Blk Cl. 4'			7½ " "	" "	8 " "
59	" 4'	" 2'	" " 4'			10 " "	" "	8 " "
60	Grvl & R 4'	Blk Cl. 4'				8' " "	" "	7½ " "
61	Grvl 3½'	Sand 1'	Sand & R 2'	Black Cl 3'		9½ " "	" "	8 " "
62	" 1½'	Grvl & R 3½'	Blk Cl 4'			9 " "	" "	7½ " "
63	C. Grvl 8'	Blk Cl. 2'				10 " "	" "	8 " "
64	" " 8	" " 3'				11 "	" "	8 " "
65	Grvl 5	Sand & R 3'	sand rock with iron ½'	Bl Cl 2'		10½ " "	Bl. Cl.	8' " "
66	" 6'	Blk Cl 5'				11 " "	Blk Cl.	8' " "
67	" 5'	Sand & R 3'	sand rock with iron ½'	Gr. Cl 2'		10½ " "	Gr Cl	8 " "
68	" 6'	Blk Cl 2'				8 " "	Blk Cl	7½ " "
69	" 3'	Sand 1'	Grvl & R 5'			9 " "	Rock	7 " "
70	C Grvl. 4'	" 1'	C Grvl & R. 3'	Gr Cl. 3'		11 " "	Gr Cl	9 " "
71	Grvl. 6'	Blk. Cl. 2'				8 " "	Rock	7 " "
72	" 3'	Sand 1'	Grvl & R 5			9 " "	"	7 "
73	C Grvl & R 2½'	Sand & R 6'				8½ " "	"	8 " "
74	Grvl 3'	Sand 1'	Grvl & loose R 4'			8 " "	"	7 "
75	" 3½'	Sand 2'	C Grvl 3'			8½ " "	"	8 " "
76	" 4'	" " 3	" " 1'			8 "	"	7' × 9'

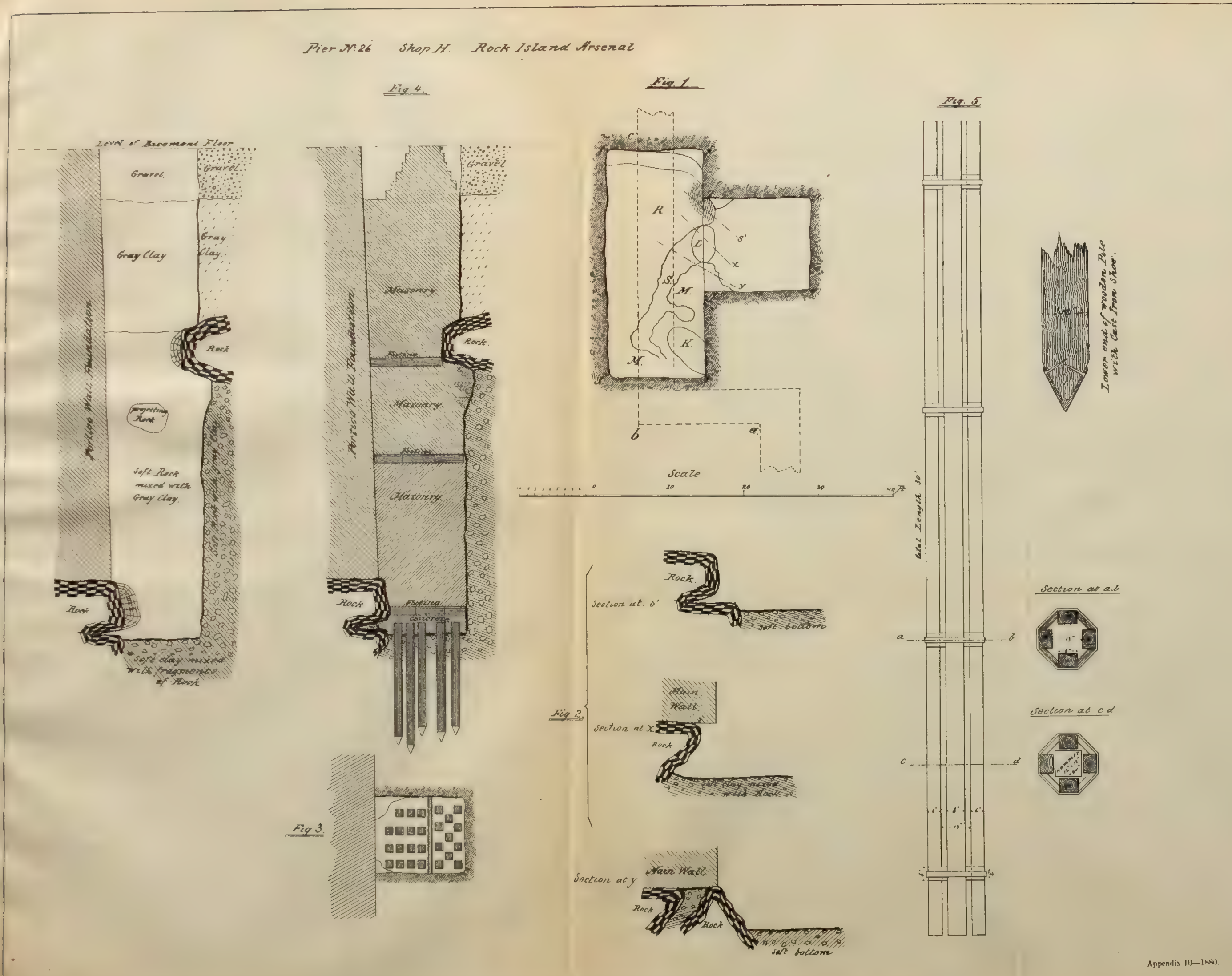
Abreviations used in Table

Grvl	for	Gravel
C Grvl	"	Coarse Gravel.
Y Cl		Yellow Clay
Bl Cl		Blue Clay.
Gr Cl		Gray Clay
Blk Cl		Black Clay
R		Rock.

PLATE III.



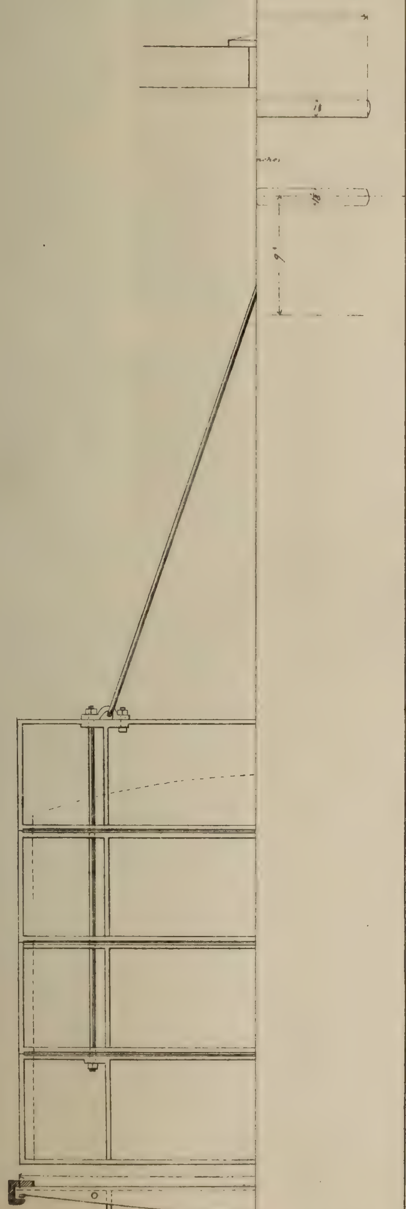
Lower end of wooden Pile
with Cast Iron Shoe.
Rock
Section at a.b.
Section at c.d.



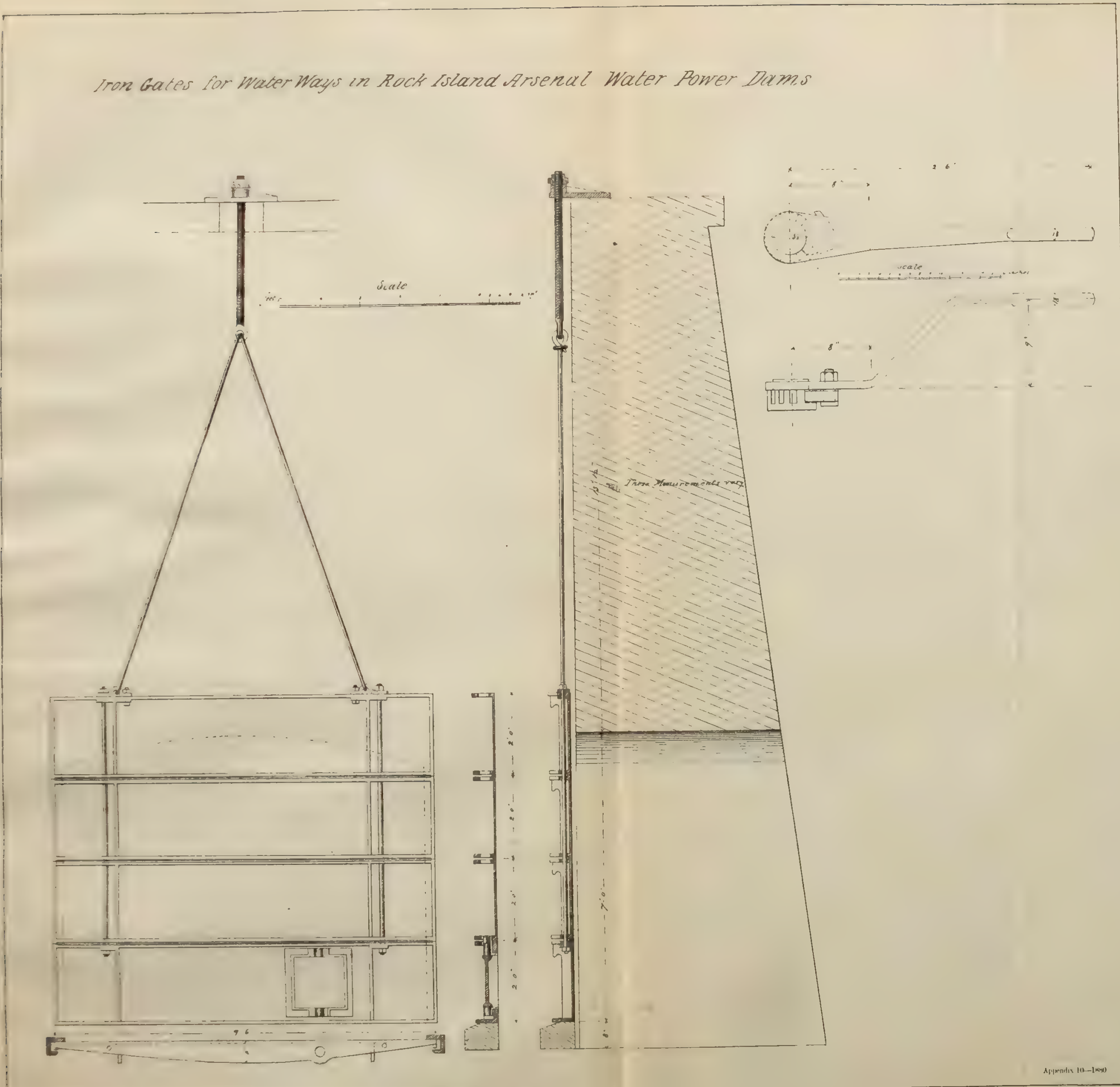
Pier Nº 26 Shop H. Rock Island Arsenal
Fig. 4.
Fig. 1.
Fig. 5.
Level of Basement Floor
Gravel.
Gravel
Gray Clay
Gray Clay.
Rock
Projecting Rock
Soft Rock mixed with Gray Clay.
Portico Wall Foundation
Soft clay mixed with fragments of Rock
Masonry
Rock.
Concrete
R
L
S.
M.
K.
M.
s'
x
y
b
a
Scale
0
10
20
30
40 ft.
Lower end of wooden Pile with Cast Iron Shoe.
total Length 30'
Section at a.b
Section at c d
a
b
c
d
Section at s'
Rock.
soft bottom
Fig. 2.
Main Wall.
Section at X.
Rock
clay mixed with Rock.
Fig 3.
Section at y
Main Wall.
Rock
soft bottom

PLATE IV.

Iron Gates fo



Appendix 10—1880.


Iron Gates for Water Ways in Rock Island Arsenal Water Power Dams
Scale
These Measurements vary
Scale
8"
2' 6"
9'
2'0"
7'0"
9' 6"

APPENDIX 11.

DESCRIPTION OF A MACHINE IN OPERATION AT THE ROCK ISLAND ARSENAL FOR PRINTING PAPER TARGETS, AND OF A BARRACK-RACK FOR SMALL-ARMS.

DEVISED BY MAJ. D. W. FLAGLER, ORDNANCE DEPARTMENT.

(Four plates.)

SIR: I have the honor to report that, in compliance with your instructions of March 18, I have devised and transmit herewith drawings of a machine for printing paper targets A, B, and C, as described in Laidley's Rifle Firing. This machine, as now used, is shown on Plate I. Fig. 1 is a side elevation of the machine, and Fig. 2 shows another view of the apparatus for rolling up the targets as they come from the printing machine.

The targets are printed by passing the paper between two rollers, one of which (the printing roller) is provided with the necessary type for printing, and the other is a cushion roller. The paper then passes over a heated drum for drying the ink, and thence to a round roller-stick upon which it is rolled up for packing.

A (Plate I, Fig. 1) is the printing roller. It is a wooden drum, 6′.5 long, and exactly 12′ in circumference, measured around the exterior of the type. It has on it three sets of type when printing the A targets, two sets when printing the B targets, and one set when printing the C targets.

The A targets are 4′ long, the B targets 6′ long, and the C targets 12′ long, so that the roller prints three A targets in one revolution, two B targets in one revolution, and one C target in one revolution.

The type is made of scrap fuse-plug metal—lead alloyed with zinc and antimony—and is cast in the required shape, flat, about 0″.3 thick, and then bent on to the drum and screwed down firmly. Its exterior surface is then turned off very accurately in a lathe to form a perfect cylinder, and the surface made perfectly smooth. As the drum is used for printing all the targets by changing the type, the type when being turned is fitted to the exact position it is to occupy while printing.

B is the cushion roller. It is a carefully turned hollow wooden cylinder, 6′.5 long, about 2′.5 diameter, covered with one thickness of Petersham cloth, over which is tightly stretched one thickness of strong muslin.

The bearings of the two rollers are arranged to be moved by means of wooden wedges, so as to press the surfaces of the rollers together with any required pressure, and roller A is also mounted nearly over roller B, so that the weight of the former may rest on the latter and thereby produce the required pressure with less friction.

Roller A is turned by one man with a crank, and the friction of surface contact turns the other roller.

The type is inked by an ordinary set of ink rollers, at G, such as are used on rotary printing-presses.

The large quantity of ink used requires some artificial heat for drying it. This is furnished by the large size army wood heater. On this is

mounted a large sheet-iron drum of the form shown in the drawing, 6′.5 long in the direction perpendicular to the plane of the picture and 4′.25 wide. All except the top surface is made cheaply of common sheet-iron. The top is made of smooth Russia iron, and curved in the arc of a circle as shown, that all parts of the paper may be held in contact with it when drawn taut.

The apparatus for rolling up the targets for packing is sufficiently shown in the drawing (Figs. 1 and 2). The roller-stick, 3″ diameter, is made round and smooth, and coated with shellac to make the roll of targets slip off readily. One of its bearing posts is hinged so that it can be thrown down out of the way, and then by turning the stick backward with the crank it is loosed in the paper roll, the roll is slipped off, wrapped in wrapping paper, tied, and stenciled. Three target "pasters" are conveniently used for fastening down the end of the paper during this operation to keep it from unrolling.

By authority of the Chief of Ordnance, the targets are packed: 50 targets A in one roll, 50 targets B in one roll, 25 targets C in one roll, and these rolls are made the unit of issue, so that issues may be made without breaking packages. Type on the printing rollers prints a division line between the targets, along which line they are to be cut apart. The machine shown on Plate II furnishes another method for accomplishing this by punching a row of holes along the dividing line, to permit pulling the targets apart, as is done with postage-stamps.

The paper is 6′ wide. It comes on rolls of about 275 yards each, and the roll is prepared for the machine by driving a wedge-shaped piece of wood into the center of each end. These pieces of wood have bearings, and are mounted on the printing machine as shown at K, on the drawing. The route of the paper while being printed is shown by the line C.

L is a frame which is revolved up into its dotted position to hold the paper off the heated drum while cutting off the end of a roll of targets for packing.

The machine shown on Plate II (referred to above) for punching a row of holes in the dividing line between the targets is as follows:

A A is an ordinary pine table 6′.5 square. The printed targets pass over this along the line *p p* as they come from the printing machine. B is the punching beam. It is made of hard wood, and a row of vertical holes, 0″.125 diameter, and 0″.25 apart from center to center, was bored through it. The punches, dull pointed and made of 0″.125 steel wire, were driven through the holes from the top. A strip of hard wood, containing corresponding die holes, is let into the table below. When the punching beam is lowered, the stripping beams C C, shod with iron (see Fig. 3), reach and rest upon the paper first, and hold it while the punching beam follows down and punches the paper. When the punching beam is raised the stripping beams remain on the paper, and hold it until the punches are drawn out of it, and then follow the punching beam up about one-half inch and allow the paper to be drawn through. All these beams are weighted with iron, are lowered with a blow, and are raised and lowered by means of the foot lever D.

This machine worked satisfactorily, but the character of the paper received for the targets was very different from that experimented upon while making the machine, and was found not to tear easily along the line of holes. With this paper it will be necessary to change the punches and place them closer together.

As great haste was required in printing the targets, the method of printing the dividing lines described above was adopted for the present.

This machine is described here, as it may be desirable to use it hereafter.

The cost of the printing machine as now used, rate of production, and cost of printing, are as follows:

COST OF MACHINE.

Printing machine complete (except type and ink-rollers)	$88 85
Type for A target (including putting on)	16 40
Type for B target (including putting on)	25 50
Type for C target (including putting on)	36 60
Ink-rollers and fittings	14 50
Winding and packing apparatus	5 25
Heating drum, pipe, and fittings	11 00
Total	198 10
Punching machine	26 20

The above includes cost of drawings and patterns, but does not include cost of experiments.

It requires about one day to change the type on the printing roller, and costs $2.50.

One man and three boys are required to operate the machines. Cost per diem	$4 50
Ink and sundries	1 50
Total per diem	6 00

The average rate of production is 1,200 A targets, 800 B targets, 400 C targets, per diem—making the cost about one-half cent each for the A targets, three-quarters of a cent each for the B targets, and one and a half cents each for the C targets.

BARRACK RACK FOR SMALL-ARMS.

(Plate III.)

APRIL 10, 1880.

SIR: I have the honor to report that in obedience to instructions contained in your indorsement of June 17, 1879, on a letter from Capt. C. Comly, chief ordnance officer, Department of Texas, I have devised and transmit herewith drawings of a barrack gun-rack.

The objects to be effected are:

First. To provide a rack in which arms can be securely locked up.

Second. To so protect the muzzles of the arms that dust, dirt, and other substances cannot get or be put into the muzzle either by design or accident.

Third. To make the rack as ornamental as is consistent with economy.

DESCRIPTION.

The rack is made to hold 20 rifles or carbines. It is made entirely of black walnut, except in certain metallic parts, which will be specified in the description.

Figs. 1 and 2, Plate 3, exhibit an adjustable rack intended for both rifles and carbines. Fig. 1 is a vertical section through the rack, with the top part lowered to the proper position for carbines. Fig. 2 is an elevation of the same rack, with the top part raised to the proper position for rifles. Fig. 3 is a plan view of the base, containing holes of the proper shape for the butts of the arms. For economy of manufacture it is made of two thicknesses of plank, that the butt holes may be cut entirely through the top plank. The two planks are so fitted together as to resemble one solid piece of wood. The butt-holes are 1″.5 deep, so that the rifle or carbine must be lifted 1″.5 to take it out of the rack.

Fig. 4 is a plan view of the muzzle holder A, and is 1″.5 thick. It is secured to the post by the iron pin *a* (Fig. 1) and this fastening is made more rigid by the metal socket *b* (Fig. 1.)

When the muzzle cover C is down on the muzzleholder the arms cannot be raised, and therefore cannot be taken out.

When the rack is open the muzzle cover is raised 1″.5 to the position shown in Fig. 5, and the arms can be lifted and taken out.

LOCKING APPARATUS.

The metal cylinder *d*, containing a spiral slot, *s*, is securely fastened to the muzzle cover C. It is reamed out and fitted nicely to the gas-pipe P. (See Fig. 5.) The exterior of this gas-pipe is also turned. The iron pin *e* is riveted into the gas-pipe and works in the spiral slot *s*. By turning the muzzle cover nearly a half turn to the right it is raised to the position shown in Fig. 5. A *lever* in the lower end of the spiral slot causes the muzzle cover to remain up when raised, and the end of the slot hurting against the pin *d* stops the turning when the cover is raised enough. The pin *f* prevents the cover from being lifted off.

When the cover is down the rack is locked, so that arms cannot be taken out, by means of the lock and bolt shown at L. The bolt *e* when

lowered is fastened in position by an ordinary lock, the key-hole of which is in the top of the muzzle cover. The key-hole is covered by a guard to keep out dirt, and when the guard is pushed aside to insert the key it is pressed against the bolt *c* by means of a spring and cam on the guard-pin. When the bolt is lifted the spring pushes the guard into a hollow in the bolt and holds the bolt up.

ADJUSTING APPARATUS.

(For adapting the rack to hold both rifles and carbines.)

The post of the gun rack is made hollow and the gas-pipe P slides up and down in it, and is secured at the required position for either rifles or carbines by means of the locking pin shown in Fig. 8, which is put through the hole *o* in the post and a corresponding hole in the pipe. This adjustment is not very easily made, but as it would have to be done only once in several years, this is not important.

The diameter of the gas-pipe is 2″.5 to give sufficient stiffness, and its exterior is turned and fitted nicely in the two metal hubs L L.

For economy of manufacture, the gun-rack post is made of two pieces of wood, and the bore is hollowed out before they are put together. They are then fitted on the hubs *h h* and turned on a mandrel. The brass ferrules *g* and *g′* are to strengthen the post. Three metal feet, *m*, are put under the base for securing the rack to the floor, and for enabling it to stand securely on uneven floors. Unless it is absolutely necessary that the same rack should be used for both carbines and rifles, it is recommended that this adjusting apparatus be omitted and that solid racks of two sizes, like the one shown in Figs. 6 and 7, be made instead.

This rack is precisely the same as the one described, except that the adjusting apparatus is left out; the post is made solid; the wooden tenon T is left on the top of the post; the muzzle holder A is secured directly to the wooden post, and only the short piece P′ of the gas-pipe is slipped over the tenon for the locking apparatus. The locking apparatus is in all respects the same as the other.

COST.

Gun racks like the one shown in Figs. 1 and 2, adjustable for both rifles and carbines, will cost $27.50 each.

Solid racks for rifles, like the one shown in Fig. 6, will cost $21 each.

Solid racks for carbines, like the one shown in Fig. 6, will cost $20 each.

If the adjustable rack is used, I would recommend that a cast-iron post be used. This would reduce the cost of this rack to $24, provided enough racks were made to warrant the making of patterns and core boxes.

JUNE 5, 1880.

After making the foregoing report I retained the model gun rack for trial and examination by officers, and to ascertain whether it was liable to injury from warping and cracking. The cover plate has warped slightly, but not enough to injure the rack or its appearance materially.

CAST-IRON BARRACK GUN RACKS.

As the gun racks made of walnut, as above described, may be deemed too expensive, upon further consideration I have been led to devise plans for making the racks almost entirely of cast iron. These plans are shown in Figs. 9, 10, and 11, on Plate IV.

Some changes in the rack are made necessary by the change of material. The rack is made entirely of cast iron, except the muzzle-holder plate, which is made of walnut to prevent marring or injuring the muzzles of the arms.

As lifting up the muzzles against an iron muzzle cover in taking out the arms might also injure the muzzles, the plans for the muzzle cover are changed as follows:

When the rack is unlocked and open there is a hole in the muzzle cover over each arm of such size and shape that the muzzle can be lifted up through the hole high enough to permit taking out the arm without letting any part of the arm hit the iron cover.

To lock the rack the muzzle cover is turned about 1.5 inches, until the holes are midway between the muzzles of the arms, and the arms cannot then be lifted. In this position the muzzle cover is locked with the same locking apparatus as that described for the walnut rack.

It is believed that the other details of construction are sufficiently shown in the drawings, and require no further explanation.

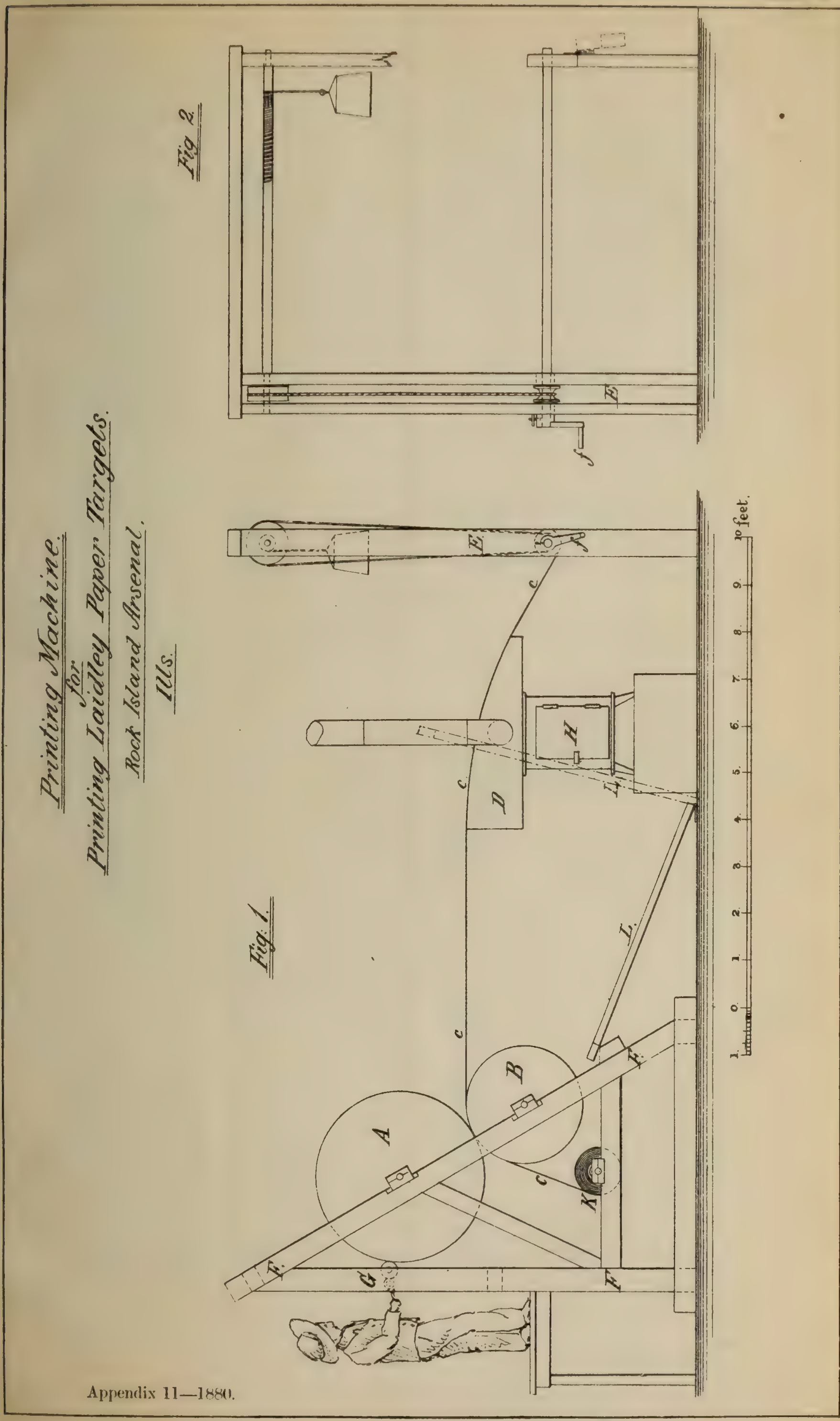
If an adjustable rack for both rifle and carbine is required, the adjusting apparatus already described is added to this rack in the same way as described for the walnut rack. It costs less in the iron rack, because the sliding hubs in the post (for the spindle) are left in the interior of the iron post in casting, and require reaming out only.

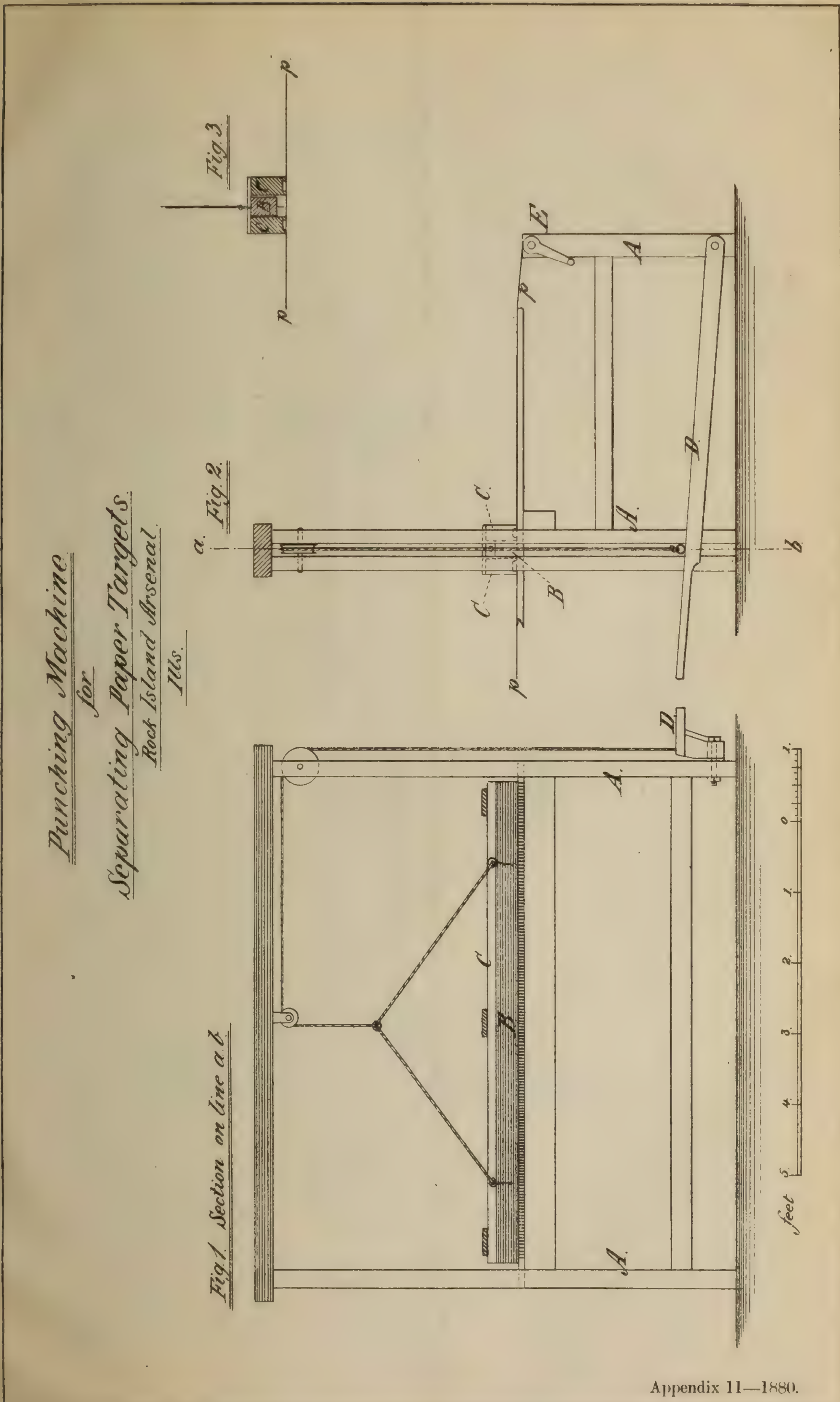
This rack can be taken apart readily for shipment, and reassembled and put up in barracks. Its cost, as shown by the appended statement, is much less than that of the walnut rack. It is, however, not so handsome as the walnut rack. It could be bronzed or handsomely colored while the castings are hot.

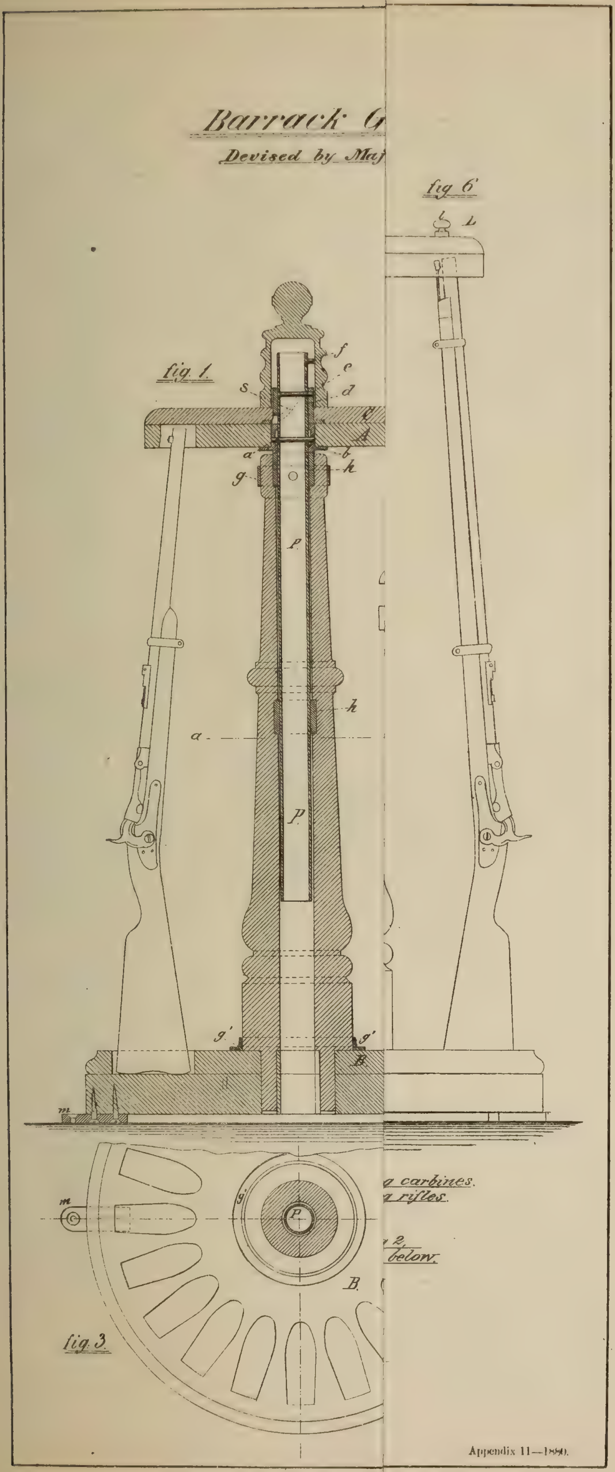
The estimated cost and weights of the iron racks are as follows: It would cost about $115 to prepare patterns, core boxes, &c. After these were prepared it would cost to manufacture in lots of fifty:

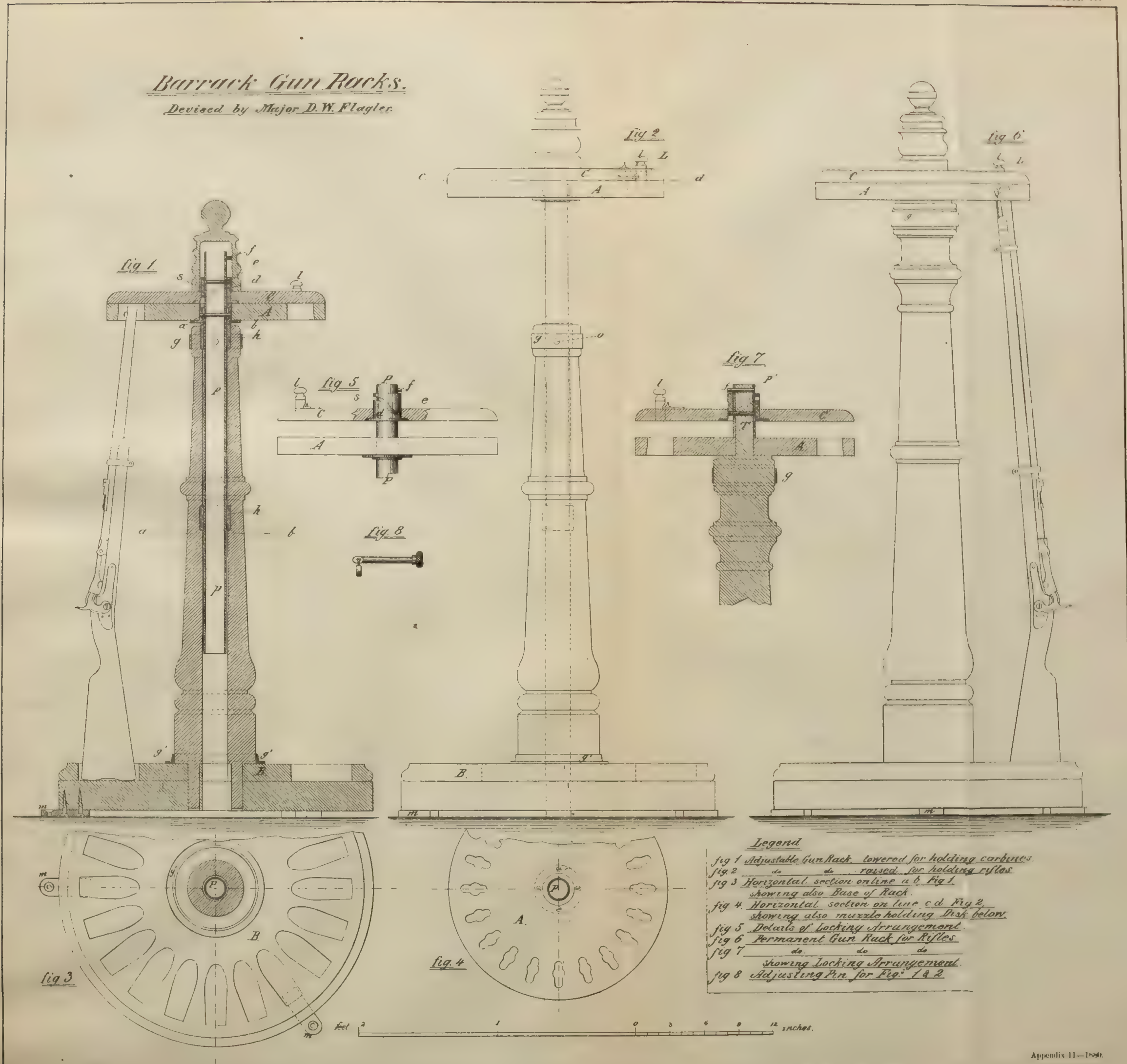
		Weight.
Permanent iron rack for carbine	$15 00	255 lbs.
Permanent iron rack for rifle	15 50	275 lbs.
Adjustable rack for both rifle and carbine	18 50	280 lbs.

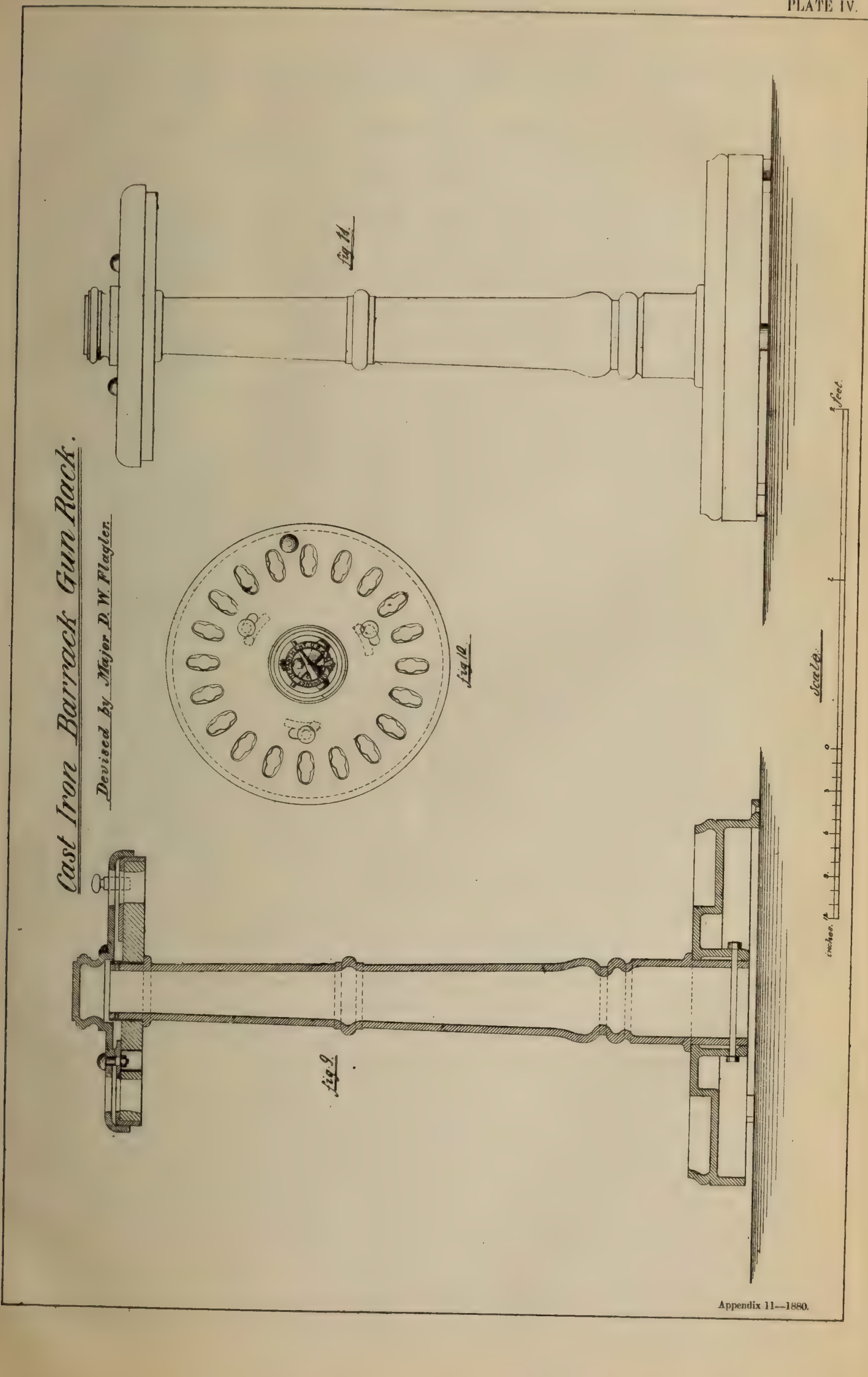
These racks would be so made that the parts could be detached for easy transportation, and the rack assembled when required for use.


Printing Machine.
for
Printing Laidley Paper Targets.
Rock Island Arsenal,
Ills.
Fig. 1.
Fig. 2.
A
B
C
D
E
F
G
H
K
L
c
f
10 feet.
1. 0. 1 2 3 4 5 6. 7. 8 9


Punching Machine
for
Separating Paper Targets.
Rock Island Arsenal
Ills.
Fig. 1. Section on line a. b.
Fig. 2.
Fig. 3.
feet
5 4 3 2 1 0 1


Barrack G
Devised by Maj
fig 6
fig. 1.
s
f
e
d
c
A
a
b
g
h
p
a
g'
B
m
carbines.
rifles.
below.
P
B.
fig. 3.


Barrack Gun Racks.
Devised by Major D. W. Flagler.
fig 1.
fig 2
fig 3
fig 4.
fig 5
fig 6
fig 7
fig 8
Legend
fig 1 Adjustable Gun Rack, lowered for holding carbines.
fig 2 do do raised for holding rifles.
fig 3 Horizontal section on line a b Fig 1.
showing also Base of Rack.
fig 4. Horizontal section on line c d Fig 2,
showing also muzzle holding Disk below.
fig 5 Details of Locking Arrangement.
fig 6 Permanent Gun Rack for Rifles
fig 7 do do do
showing Locking Arrangement.
fig 8 Adjusting Pin for Figs 1 & 2
feet 2 1 0 3 6 9 12 inches.


Cast Iron Barrack Gun Rack.
Devised by Major D. W. Flagler.
fig. 9.
fig. 10.
fig. 11.
Scale.
inches.
feet.

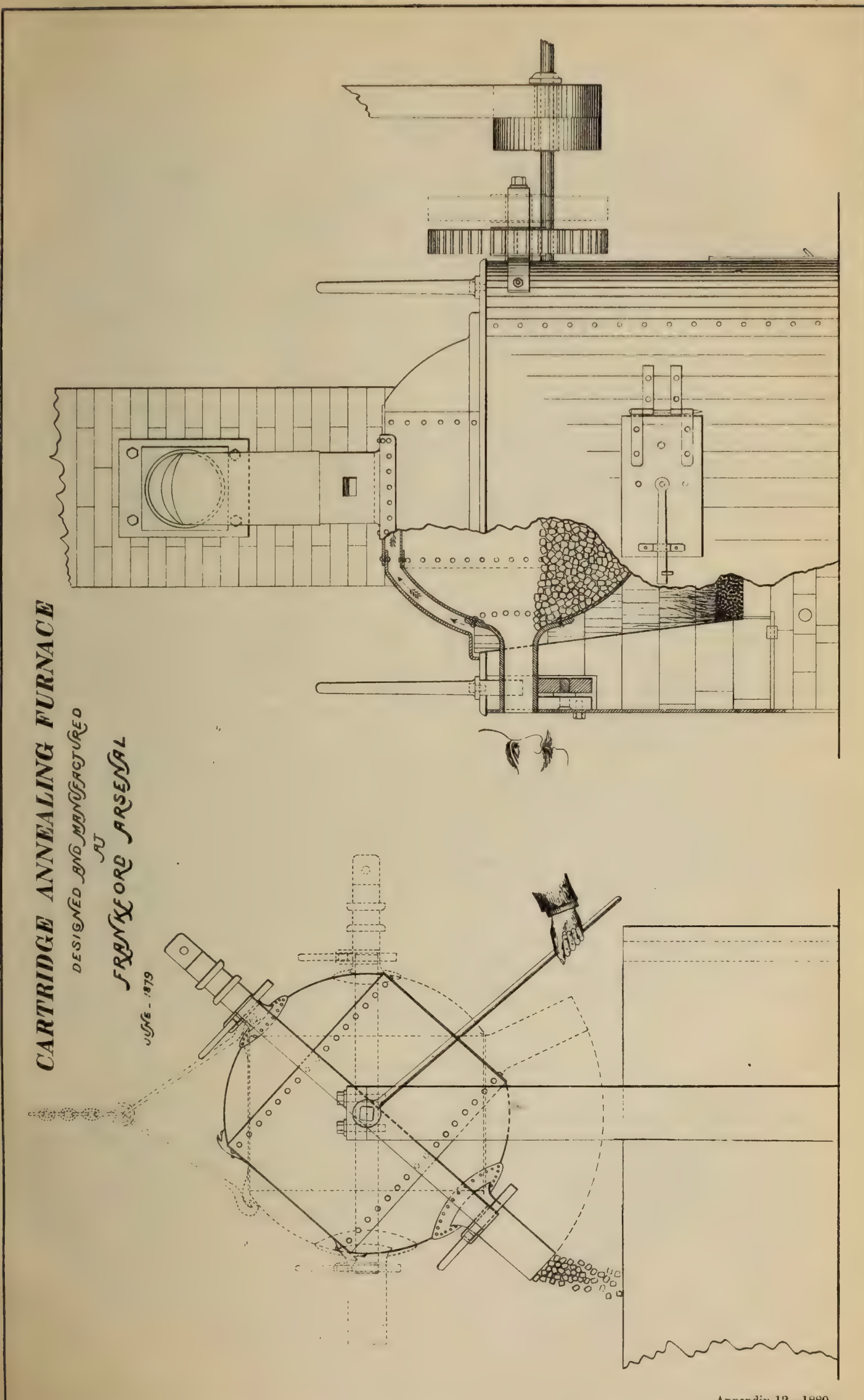
APPENDIX 12.

REPORT ON A NEW CARTRIDGE ANNEALING FURNACE IN USE AT FRANKFORD ARSENAL.

BY LIEUT. COL. J. M. WHITTEMORE, ORDNANCE DEPARTMENT.

(One plate.)

SIR: I have the honor to submit the following report upon the new annealing furnace now in successful operation at this arsenal. This furnace is for annealing copper or brass shells, cannon-primer tubes, &c. It consists of the furnace proper, constructed of boiler iron, lined with fire-bricks, and arranged with flue and cold blast for draft and heat; of an annealing retort, cylindrical in shape, with closed ends of hemispherical form. From these ends project trunnions which revolve on friction rolls attached to the furnace. The left trunnion, looking toward the furnace, is hollow, and subserves several useful purposes. It is a peep-hole for observing the degree of heat to which the charge is being raised, an outlet for the smoke into which the oil on the shells is converted, a means of obtaining samples for test, and of emptying the charge when sufficiently annealed. The annealing accomplished in this tight-jointed receptacle possesses several advantages over the old plan. In the latter the cylindrical vessel used was pierced with holes and revolved with its charge over a charcoal fire. The surface of the shells became considerably oxidized from exposure to the atmosphere and took up some dirt, as ashes from exterior surroundings, during the process. By the new plan the charge is protected from the direct action of the fire, and the gases and smoke generated and expanded inside the retort flow out through the hollow trunnion. By the old method charcoal was necessary as a fuel to guard against the sulphur and other gases which would be generated from burning anthracite coal. Anthracite coal is used with the new retort, and the shells are annealed with less oxidation of their surfaces, and consequently require less pickling and cause less wear upon machinery and tools in the continued process of drawing. Ten thousand shells or thirty thousand cannon-primer tubes is a full charge for the retort. From 180,000 to 200,000 shells can be annealed in one day of ten hours at an expense of about $5.25. An equal number by the old method would take three days and six hours at an expense of about $18.75. New process—amount of anthracite coal consumed in annealing 180,000 shells=600 pounds at a cost of $1.50. Old process—15 barrels charcoal at 35 cents=$5.25. A crane takes the retort from the furnace and deposits it upon a cradle from which it is readily emptied. Retort with full charge weighs about 600 pounds. The furnace has a hinged wrought-iron cover, which is lowered over the retort during the operation of annealing and raised when the retort is removed. Also a hinged flue, which fits into an opening in the cover connecting it with the draft. The accompanying drawing (Plate I) shows the general construction and operation of the furnace. This furnace was designed by Mr. Jabez H. Gill, master machinist at this arsenal. By your authority its construction was commenced, with new annealing house, by me in July, 1879, and completed about November 1, same year, from which time it has been in constant use. A special annealing house was provided for the purpose of concentrating the work by more direct communication with the shop where the cartridge shells are made.


CARTRIDGE ANNEALING FURNACE
DESIGNED AND MANUFACTURED
AT
FRANKFORD ARSENAL
JUNE - 1879

APPENDIX 13.

PORTABLE ARM RACK FOR COMPANY QUARTERS.

SUGGESTED BY CAPT. F. H. PHIPPS, ORDNANCE DEPARTMENT.

(One plate.)

Material, &c., for arm rack holding twenty guns:

TOP.

Made of two 1-inch white-pine boards, glued together, crossing grain of wood. Diameter of top, 13 inches. Top cut to receive twenty rifles. The guns are held in place and secured by a strap of iron 1 inch wide, leather covered, hinged, and secured on opposite side by padlock; hinge and padlock fastening secured by irons shown in Plate I.

BOTTOM.

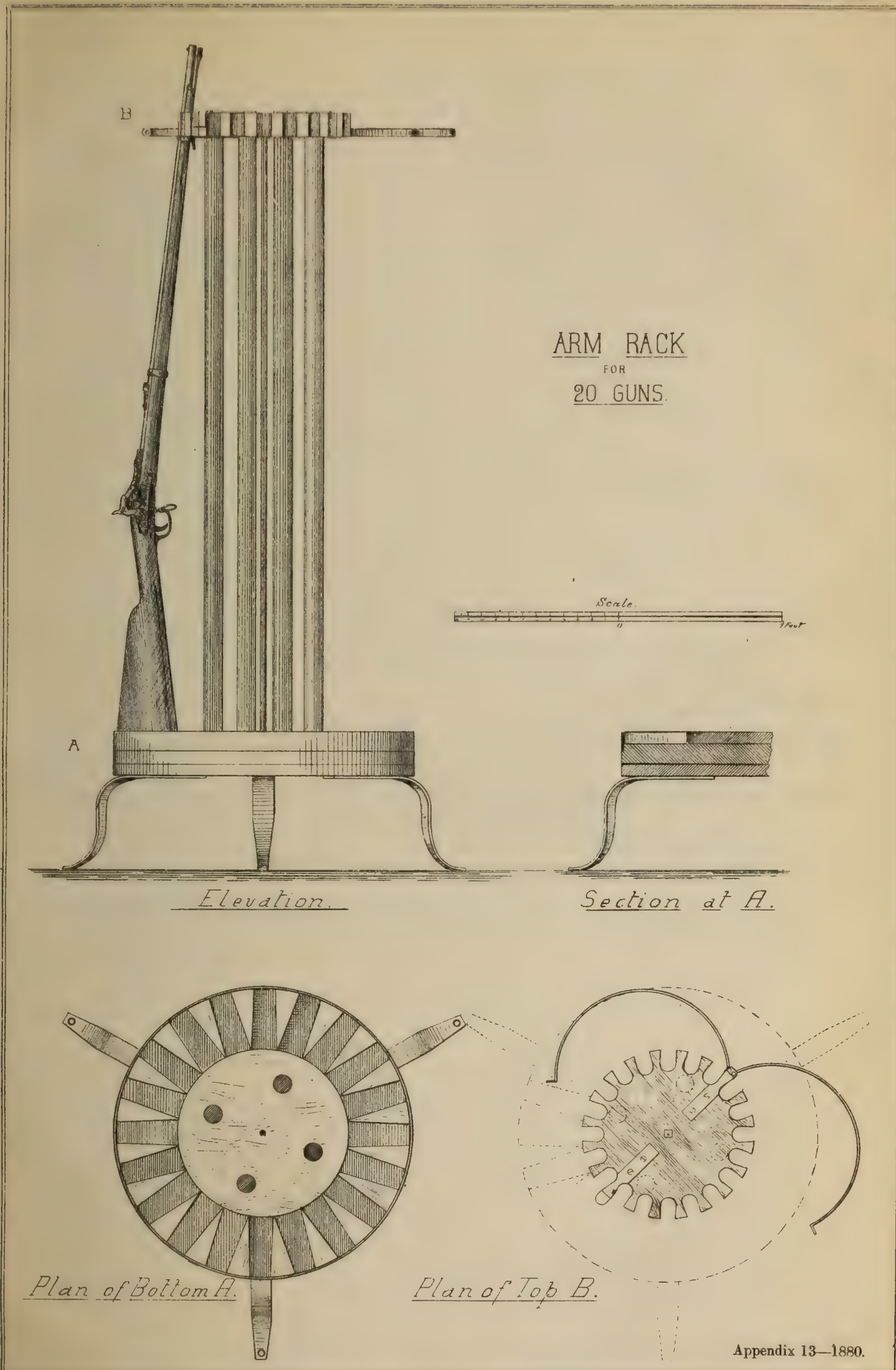
Made of one 2-inch and one 1-inch white-pine boards, 22 inches in diameter, and one $\frac{7}{8}$-inch board of white pine, $12\frac{1}{2}$ inches in diameter, glued together, crossing grain. Twenty triangular-shaped partitions of poplar, $1\frac{3}{4}$ inches wide at base, by $4\frac{5}{8}$ inches long, separate butts of rifles. A band of sheet-iron $1\frac{1}{2}$ inches wide, secured by screws, whose heads are filed to prevent removal, surrounds the upper part of base, the top being flush with top of partition.

Four round pieces of white pine, $1\frac{1}{2}$ inches in diameter and 3 feet 11 inches in length (total), connect top and bottom of frame. A rod of iron, $\frac{3}{8}$-inch diameter, with square head at top and threaded for nut at bottom, binds the whole together. In lieu of the four wooden posts and iron rod a single one of gas-pipe might be substituted.

The distance between the top and bottom is such that the upper band of rifle just touches the under side of top; and all is so arranged that, without removing the padlock and turning back the straps, no rifle can be removed. The three iron feet which support the whole can be screwed to the floor of the barracks.

RACKS FOR CARBINES

are similarly constructed, differing only in height and in the arrangement of top, which, instead of being cut entirely through to receive the barrel, is cut to the depth of only $\frac{3}{4}$ inch to receive the muzzle of the carbine. This rack is almost identical with the one suggested by Major Comly; the principle is the same, but it is stronger and its cost reduced about one-fourth.


ARM RACK
FOR
20 GUNS.
B
A
Scale.
Elevation.
Section at A.
Plan of Bottom A.
Plan of Top B.

APPENDIX 14.

REPORT ON FOREIGN LIFE-SAVING ROCKETS AND ROCKET APPARATUS, 1880.

BY LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT.

(Nineteen plates.)

NATIONAL ARMORY,
SPRINGFIELD, MASS.,
August 27, 1880.

SIR: I have the honor to submit herewith my report on foreign life-saving apparatus.

Nineteen plates, six of which are photographs, accompany the report.

Very respectfully, your most obedient servant,

D. A. LYLE,
First Lieutenant, Ordnance Department, U. S. A.

The CHIEF OF ORDNANCE, U. S. A.,
(Through the commanding officer of the National Armory.)

18 ORD

CONTENTS.

PART IV.

English life-saving apparatus.

PART V.

Hooper's life-saving rocket apparatus.

PART VI.

Conclusion.

LIST OF PLATES.

EXPLANATION.

Plate I.

Fig. 1. Longitudinal section of Russian life-saving rocket.
- H. Head.
- C. Rocket case.
- B. Base.
- VV. Vents.

Fig. 2. Front elevation of rocket.
Fig. 3. Rear elevation of rocket.
Fig. 4. Side elevation of rocket stick, with a partial section of the rocket at the front end.
Fig. 5. Rear elevation of rocket stick.
Fig. 6. Side elevation of Russian life-saving rocket, showing stick in position with cap over base of rocket.
Fig. 7. Rocket chain.

Plate II.

Fig. 1. Side elevation of Russian rocket stand.
- T. Rocket tube.
- F. Flanges.
- E. Opening in sides.
- C. Horizontal axis.
- G. Slotted brass support.
- A. Clamp screw.
- H. Tripod head.
- S. Shoulder on support.
- B. Lower clamp screw.

Fig. 2. Front elevation of rocket tube, showing outline of rocket when in position.
Fig. 3. Rear elevation of rocket tube, showing flanges.
Fig. 4. Section of rocket tube and vertical support on line D C, Fig. 1.
Fig. 5. Plan of tripod head and legs.
Fig. 6. Leg of tripod.
Fig. 7. Portfire holder.

Plate III.

Fig. 1. Side elevation 5^{cm} German life-saving rocket.
B. Base.
E F. Ribs.
C. Body or case.
H. Head.
Fig. 2. Longitudinal section of 5^{cm} rocket.
D. Base ring.
Fig. 3. Cross-section through E F, Fig. 1.
Fig. 4. Rear elevation of rocket.
Fig. 5. Side elevation of loop for chain, with section of rear part of rocket stick.
Fig. 6. Rear elevation of rocket stick.
Fig. 7. Rocket chain.
Fig. 8. 5^{cm} rocket and stick prepared for firing.

Plate IV.

Fig. 1. Side elevation of 8^{cm} German life-saving rocket.
B. Base.
E F. Ribs.
C. Body or case.
H. Head.
Fig. 2. Longitudinal section of 8^{cm} rocket.
D. Base ring.
B., C., H., E F. } Same as Fig. 1.
Fig. 3. Rear elevation of rocket without the stick.
Fig. 4. Cross-section through E F, Fig. 1.
Fig. 5. 8^{cm} rocket stick.
Fig. 6. Rear elevation of stick.
Fig. 7. Rocket chain.

Plate V.

Fig. 1. Side elevation of 8^{cm} German anchor rocket for life-saving purposes.
A. Anchor head.
B. Base.
C. Case or body.
F F. Flukes.
Fig. 2. Rear elevation of same.
Fig. 3. Partial longitudinal section of 8^{cm} rocket.
Fig. 4. Partial longitudinal section of anchor rocket stick (sheet-metal tube), showing the rivets where edges lap together.
Fig. 5. Rear elevation of rocket stick.
Fig. 6. Rocket chain.

Plate VI.

Fig. 1. Side elevation of German rocket stand.
Fig. 2. Top view of rocket trough.
Fig. 3. Section in front of rear end of trough.
Fig. 4. Section at middle of trough.
Fig. 5. Section near front end of trough.
Fig. 6. Section of trough and front elevation of upper portions of the legs, showing horizontal axis and method of connecting.
Fig. 7. Firing staff, showing a *pillenlicht* in position in clamp.

Plate VII.

Fig. 1. Side elevation of German firing lock with the firing pin withdrawn ready for firing.
Fig. 2. Top view of firing lock with firing pin withdrawn.

Fig. 3. Longitudinal section of lock tube, showing interior construction.
Fig. 4. Longitudinal section of tube after firing, showing *pillenlicht* and fulminate.
H. Stock.
I. Lock tube.
B. Firing bolt.
F. Bolt spring.
A. Bolt pin.
D. Firing pin.
T. Firing lever.
S. Firing-lever spring.
E. Bell-mouthed cavity.
P. *Pillenlicht.*
Fig. 5. German *pillenlicht*, side and end elevations.
Fig. 6. English portfire cylinder.
Fig. 7. English portfire.
Fig. 8. English rocket fuse.

Plate VIII.

Fig. 1. Front elevation of German faking box.
Fig. 2. Plan of top of German faking box.
Fig. 3. Rear elevation of German faking box.
Fig. 4. End elevation of German faking box.
Fig. 5. Side elevation of frame and faking pins.
Fig. 6. Plan of frame, showing holes for pins.

Plate IX.

Fig. 1. Side elevation English (Boxer) life-saving rocket and rocket stick, showing method of attachment of line, stick, and washers.
Fig. 2. Longitudinal section of Boxer life-saving rocket.
Fig. 3. View of rear end of rocket.
Fig. 4. View of front end of rocket.
Fig. 5. English rocket stick, showing method of attaching line.
A. Front cylinder.
B. Rear cylinder.
C. Head clip.
D. Base clip.
E. Clip pin.
F. Diaphragm.
G. Base plug.
H. Head.
I. Cavity in the rocket composition or "bore."
L. Rocket stick.
M. Rocket line.
N. Brass washer.
O. India-rubber washer.
V. Vent.

Plate X.

Fig. 1. Side elevation of English life-saving rocket stand "mark IV."
Fig. 2. Elevation of front part (right-hand side), showing graduated arc and plummet.
Fig. 3. Partial section, showing front view of horizontal axis and method of attaching legs.
Fig. 4. Cross-section of curved trough or pry pole.
Fig. 5. Cross-section of rectangular trough.
A. Rectangular trough or body.
B. Sockets for upper ends of legs.
C. Horizontal axis.
D. Leg spikes and ground spike.
O. Openings for introducing portfire.
L. Legs.
P. Curved trough or pry pole.
S. Strap and buckle.

Plate XI.

Fig. 1. Side elevation of Hooper's life-saving rocket, showing swivel and part of chain.
Fig. 2. Longitudinal section of Hooper's rocket.
Fig. 3. Rear view of rocket, showing vents and curved flanges.

Fig. 4. Rocket chain.
- A. Rocket case or body.
- B. Base.
- H. Head.
- VV. Vents.
- S. Swivel.

Plate XII.

This plate is an enlarged copy of the drawings that accompanied the letters patent

Fig. 1. Side elevation of Hooper's life-saving rocket.
Fig. 2. Longitudinal section of same.
Fig. 3. Cross section on A B, Fig. 2.
Fig. 4. Rear elevation of rocket, showing vents.
Fig. 5. Side elevation of Hooper rocket stand, showing a rocket in position for firing.
Fig. 6. Rear view of rocket stand, with rocket in position for firing.

NOTE.—The Hooper life-saving rocket is of English manufacture.

Plate XIII.

Fig. 1 shows deviation of Boxer life-saving rocket and rocket line from the plane of fire due to the effect of the wind.

Fig. 2 shows deviation of Boxer life-saving rocket and rocket line from the plane of fire due to a side wind.

Plate XIV

Shows Russian rocket, rocket stand, and method of firing.

Plate XV

Shows 5^{cm} German rocket, rocket stand, and method of firing.

Plate XVI

Shows 8^{cm} German rocket, rocket stand, and method of firing.

Plate XVII

Shows 8^{cm} German anchor rocket, rocket stand, and method of firing.

Plate XVIII

Shows English life-saving rockets, rocket stand, method of firing, fuse-box, portfire box, rocket-carrying box, faking box, and tripod for wreck light with light in position.

Plate XIX

Shows Hooper's life-saving rocket on the German stand, also effect of firing on Hooper rockets—one having the head blown out and the other being ruptured longitudinally.

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D. A. LYLE,
Lieutenant of Ordnance.

NATIONAL ARMORY, *August* 25, 1880.

INTRODUCTORY NOTE.

In the spring of the year 1879, several lots of foreign life-saving rockets and rocket-apparatus which had been consigned to Capt. J. H. Merryman, United States Revenue Marine, inspector of life-saving stations, were sent by that officer to Sandy Hook, N. J., for examination and trial.

Instructions were given that inventories should be made of the apparatus, and that each article should be carefully inspected.

Lieut. D. A. Lyle, Ordnance Department U. S. A., was directed to make the inspection, and to familiarize himself with all the details of the several systems of apparatus. He was also directed to fire a few rockets of each kind in order to ascertain their condition as regards safety and efficiency.

It was deemed best to store these rockets in an ordinary building, open to sea-air for several months, in order to see what effect the salt air had upon the rocket cases.

In the latter part of the same year the examinations and trials were made.

The results with the Russian and Hooper life-saving rockets were so unsatisfactory that the firing with them was continued until the supply was exhausted.

It was decided that the other rockets should remain in store for at least another year, then to be examined and inspected.

Embodied in this report will be found descriptions of the different apparatus, together with the results of the experimental trials.

PART I.

INVENTORIES OF FOREIGN LIFE-SAVING ROCKET APPARATUS SENT TO SANDY HOOK, N. J., BY CAPT. J. H. MERRYMAN, UNITED STATES REVENUE MARINE, INSPECTOR UNITED STATES LIFE-SAVING STATIONS, FOR TRIAL AND EXPERIMENT.

I.—INVENTORY A.

Russian life-saving rockets and rocket apparatus.

No.	Name of article.
50	Russian life-saving rockets.
1	Rocket stand.
1	Port-fire holder.
1	Rocket chain.
1	Coil rocket line—loose twist—hemp.

II.—INVENTORY B.

German life-saving rockets and rocket apparatus.

No.	Name of article.
36	5^{cm} German life-saving rockets.
36	5^{cm} German life-saving rocket sticks and chains.
40	8^{cm} German life-saving rockets.
40	8^{cm} German life-saving rockets, sticks, and chains.
12	8^{cm} German anchor rockets.
12	8^{cm} German anchor sticks and chains.
4	German rocket stands.
4	German faking boxes and lines.
4	Firing staves or *pillenlichte* holders.
4	Firing locks.
100	*Pillenlichte.*

III.—INVENTORY C.

Boxer life-saving rockets and rocket apparatus (English).

No.	Name of article.
216	Boxer 12-pounder life-saving rockets.
216	Boxer 12-pounder life-saving rocket sticks.
216	Iron pins for attaching rockets to sticks.
216	Brass washers.
216	India-rubber washers.
12	Rocket stands or machines, "Mark IV."
12	*Boxes, wood, for port-fires.
48	Boxes for carrying single rockets, with braces.
288	Port-fires in tin cylinders, of 24 port-fires each.
1	Box rocket fuses.
36	Lights for illuminating wrecks.
12	Stands or tripods for lights illuminating wreck.

* Each of these boxes will carry 24 port-fires, 30 detonating primers in a small cylinder, and 2 port-fire holders. No primers or holders were sent with the apparatus.

IV.—INVENTORY D.

Hooper's life-saving rockets.

No.	Name of article.
24	Hooper life-saving rockets.
30	Pieces of slow match.

NOTE.—No stand was found with these rockets.

PART II.

RUSSIAN LIFE-SAVING APPARATUS.

I.—RUSSIAN LIFE-SAVING ROCKET.

(Plate I.)

1.—DESCRIPTION.

The Russian life-saving rocket is made of sheet iron, about one-tenth (0″.1) of an inch in thickness. The body is a cylindrical tube, closed at the front end by a metallic head, held in position by four short screws.

The rear end is closed by a diaphragm, which is perforated by six vents or fuse holes, equidistant circumferentially, whose centers are on the circumference of a circle concentric with the diaphragm.

An axial hole in the diaphragm has a female screw thread cut on its interior surface to engage the male thread on the rocket stick.

The body is fastened to the perforated disk by crimping and by short iron pins. The cylinder is filled with rocket composition.

The construction of the rocket stick is shown in Fig. 4. The body of the stick is made of light wood, cylindrical near the base and tapering to the front, forming the frustum of a cone. The front end of the stick, which screws into the rocket, is made of wrought iron, hollow at its base for the insertion of the wooden body. The latter is held in place by screws. The rear end of the body is rounded, and on one side carries a strong iron hook, about five (5″) inches in length, with its point turned towards the front, and curved slightly outwards from the axis of the stick.

A curved steel spring is placed between the point of the hook and the shank strap to prevent the egress of the ring of the rocket chain after firing. This hook is bolted to the wooden body of the rocket stick, as shown in the figure.

When prepared for packing, the rocket sticks are screwed into the rockets and the fuse holes or vents are covered by disks of water-proof tarred cloth.

The diameter of the disk is enough larger than that of the rocket to admit of its being folded over the end of the rocket and secured by several turns of twine, tied tightly around it.

The whole rocket, except the wooden body, is then treated with a coat of black paint.

The cap or disk must be cut away before firing, in order to expose the fuse holes.

2.—PRINCIPAL DIMENSIONS, WEIGHTS, ETC.

		Inches.	Centimeters.
Rocket body	Length	25.25	64.12
	Exterior diameter	3.2	8.13
	Interior diameter	3.0	7.62
Total length of rocket		27.2	69.08
Total length of rocket stick		29.2	74.16
Total length of rocket and stick		55.5	140.97
Length filled with composition		23.1	58.67
Maximum diameter of stick		2.8	7.11
Diameter of vents or fuse holes		0.6	1.52
Number of vents, six.			
		Pounds.	Kilos.
Average weight of rocket and stick		25.5	11.56

For detailed dimensions and method of construction, see Plate I.

3.—PACKING.

The rockets, with sticks attached, are packed in boxes containing five each. The boxes are very heavy, and are made of 2-inch plank.

Clamps are placed at each end of the box, and are notched to fit the rockets. A strip of felt is placed along the edge of each clamp above and below the rocket.

The lid has two hinges on one side so that the box may be opened, the rockets used, and the box refilled. Screws hold the top securely to the sides in transportation.

An annealed iron wire passed through the side and top of the box on the edge opposite the hinges, has the ends drawn together and held firmly by a leaded seal put on by the inspecting officers of the Imperial Russian Government. This prevents tampering with the contents without detection. The seal bears the date of packing (1876).

The boxes were covered with coarse felt an inch or more in thickness, over which was a wrapping of gunny sacks and matting; the whole firmly bound with hemp cordage.

II.—RUSSIAN LIFE-SAVING ROCKET STAND.

(Plate II.)

1.—DESCRIPTION.

This stand is a rectangular tube of sheet-iron mounted upon a wooden tripod. The cross-section of the tube is a square with one of its diagonals situated in a vertical plane when the stand is in position for use. This hollow parallelopipedonal tube is formed from a single piece of sheet-iron. The longitudinal faces forming the lower edge do not join to complete the regular figure, except for two (2″) inches at the lower end, but are bent outwards from each other, forming two parallel flanges, Figs. 1 and 4. These flanges are 1″.7 wide, and have a space half an inch wide between them throughout their length.

The space between the flanges serves as a channel for the grappling hook on the under side of the rocket-stick to slide in when the rocket is fired.

It is also necessary for the same purpose in placing the rocket in position before firing.

The rear end of the square tube is bound and strengthened by a band of strap iron 2″ wide and one-tenth (0″.1) of an inch thick.

The front end of the tube is reinforced in a similar manner, but with

this difference: The band at its lower edge has a cylindrical tube (Figs. 1, 2) 1''.7 in diameter, projecting to the front 2''.3, for the purpose of holding the ring of the rocket chain.

This short tube embraces the front ends of the flanges of the body, and has a longitudinal slot, corresponding in width to the space between the flanges along its upper surface to permit the passage of the rocket hook.

A rectangular notch 1''.1 deep is cut in the lower side to accommodate the upper link of the rocket chain when the ring is placed over the projecting tube.

Near the middle of the longitudinal bottom flange on the right-hand side of the body tube is attached a rectangular brass plate, 10'' long and 1''.6 wide, with a lug and eye-hole projecting from its under edge near the middle. Through this eye-hole passes the horizontal axis.

In a corresponding position on the left side is a semicircular brass plate attached to the other flange. The arc of this plate is graduated into degrees, in order to indicate the elevation of the axis of the main tube.

A lug and eye-hole at the center of this arc admits of the insertion of the horizontal axis.

A slotted brass support (G, Figs. 1 and 4) with holes pierced through the upper ends of the vertical arms sustains the horizontal axis (C, Figs. 1 and 4) that carries the rocket tube (T, Figs. 1 and 4) and its graduated arc.

A clamp screw (A, Fig. 4) passes through this support from the right side and clamps the arc in any given position. All motion in altitude within the limits of the scale is governed by this screw. The lower end of the support (G, Fig. 4) terminates in a cylindrical tenon 3''.2 in length and 1''.2 in diameter, which fits in a corresponding hole in the tripod head (H, Fig. 5).

A shoulder (S, Fig. 4) on the support rests upon the top of the tripod-head when the clamp screw (B, Figs. 1 and 5) is loosened.

The tripod (Fig. 5) is composed of a head (H), three legs and a clamp screw (B).

The head is of brass. This piece is a hexagonal prism in form, with narrow longitudinal projections, or lugs, on the alternate faces for the attachment of the legs.

These projections are 120° apart. Opposite one of them is a rectangular seat through which the clamp screw (B, Fig. 5) passes that controls the motion in azimuth and the limited vertical motion of the support and its superincumbent weight.

The head is pierced longitudinally by an axial hole for the reception of the tenon of the support. The legs are made of wood, shod at their lower ends with pointed iron shoes, and encircled by narrow iron bands near their upper extremities.

The upper ends of the legs are slotted vertically to receive the projections on the *head*, to which they are fastened by iron pins.

Two elliptical openings (E, Figs. 1 and 2), opposite to each other, are made in the upper sides of the tube for the insertion of the port-fire to ignite the rocket composition.

2.—PRINCIPAL DIMENSIONS, WEIGHTS, ETC.

		Inches.	Centimeters.
Total length of rocket-tube		53.3	135.38
Cross-section, square	Exterior	4.3	10.92
	Interior	4.1	10.41

	Pounds.	Kilograms.
Weight of rocket stand	39.0	17.69
Weight of rocket chain	4.625	2.17
Weight of port fire handle	0.5625	0.25
Total weight without packing box	44.1875	20.13
Weight of coil of rocket line	62.0	28.12

For other details, see Plate II.

3.—PACKING CASE FOR ROCKET STAND.

The rocket stand and port-fire holder are securely packed in a long box with a hinged lid, closed by a hasp. This box has a handle at each end for convenience in transportation.

4.—DIMENSIONS AND WEIGHT.

		Inches.	Centimeters.
Exterior dimensions of box for rocket stand	Length	69.0	175.26
	Width	16.375	41.65
	Depth	9.5	24.13

	Pounds.	Kilograms.
Total weight of box and stand	99	44.90
Weight of packing box	60	27.21

III.—PORT-FIRE HOLDER.

(Plate II, Fig. 7.)

A port-fire holder or firing staff accompanies the rocket stand. It is a simple wooden handle with a bent head of brass. The brass head is hollow and is slitted on the sides so as to form a rude clamp. The port-fire is inserted in the split end of the head and then ignited in the usual manner.

IV.—ROCKET CHAIN.

(Plate I, Fig. 7.)

This is a hand-made iron chain, six (6′) feet in length, terminated at one end by a ring two (2″) inches in diameter. The ring is placed over the tubular projection on the front end of the rocket stand in firing. The other end of the chain is fastened to the end of the rocket line.

V.—ROCKET LINE.

This is a loosely-twisted hemp line about the size of the No. 8 or No. 9 service lines. The Russian method of coiling or faking the line is unknown, as no instructions were received with the apparatus.

VI.—METHOD OF USING.

The rocket stand is taken from the box, the legs of the tripod extended, and the stand placed at the firing point. The index being clamped at zero on the graduated arc, the tripod is leveled by the eye by making the axis of the rocket tube horizontal. This can only be done approximately; then loosen the lower clamp screw and swing the stand around until it points in the desired direction. Clamp the vertical spindle and by turning the upper clamp screw to the left the required elevation may be given; after which the screw must be tightened, in order to retain the tube in place. Take a rocket from its box, tear off

the cap over the vents, insert the rocket, base first into the rectangular tube with the hook on the stick gliding down between the flanges on the lower side of the tube. When the hook strikes the band at the lower end of the rocket tube, the rocket is in position for firing. Place the fakes or faking box in front of the stand, put the ring of the chain over the cylindrical tubular projection on the front end of the stand, letting the chain attached to the line hang below. Stand clear of the line, and, with a port-fire inserted in the holder, advance and ignite the rocket by thrusting the port-fire gently through one of the elliptical openings in the rocket tube. Care must be taken not to disturb the aim.

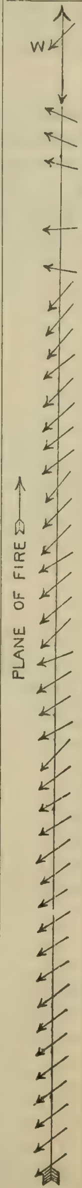
VII.—Action.

An instant after the composition in the base of the rocket is ignited, the latter leaps forward guided by the rocket tube, and as it leaves the tube the hook engages the ring of the chain attached to the line and carries out the chain and line.

The chain should be fastened to the line in advance, before it is wanted for use.

VIII.—Experiments with Life-Saving Apparatus at Sandy Hook, N. J.

1.—*Record of firings with Russian life-saving rockets and apparatus.*

Date.	Number of fire.	Elevation.	Kind of rocket stand.	Rocket, kind of.	Primer.	With what fired.	Where fired.	Line attached or not.	Rocket exploded in air or not.	Wind. Direction.	Wind. Velocity.
1879.		°									
Oct. 18	1	32	Russian	Russian life-saving rocket.	None	Port-fire (English).	Down beach	Yes	Yes.		
18	2	35	...do	...do	..do	...do	Out to sea	No.	Yes.		
18	3	35	...do	...do	..do	...do	...do	No.	Yes.		
18	4	30	...do	...do	..do	...do	...do	No.	No.		
20	5	43	...do	...do	Quick-match.	...do	Down beach	No.	Yes.		
20	6	43	...do	...do	..do	No further	record of	this	rock't		
22	7	35	...do	...do	..do	Port-fire (U. S.)	Out to sea	No.	Yes.		
22	8	35	...do	...do	..do	...do	...do	No.	Yes.		
22	9	35	...do	...do	..do	...do	Down beach	No.	Yes.		
22	10	35	...do	...do	..do	...do	...do	No.	Yes.		
22	11	35	...do	...do	..do	...do	...do	No.	Yes.		
22	12	35	...do	...do	..do	...do	...do	No.	Yes.		
22	13	35	...do	...do	..do	...do	...do	No.	Yes.		
22	14	35	...do	...do	..do	...do	...do	No.	Yes.		
22	15	35	...do	...do	..do	...do	...do	No.	No.		
Nov. 14	16	30	German	...do	..do	...do	Out to sea	No.	Yes.		
14	17	25	...do	...do	..do	...do	...do	No.	Yes.		
14	18	25	...do	...do	..do	...do	...do	No.	Yes.		
14	19	25	...do	...do	..do	...do	...do	No.	Yes.		
14	20	25	...do	...do	..do	...do	...do	No.	Yes.		
14	21	25	...do	...do	..do	...do	...do	No.	Yes.		
14	22	25	...do	...do	..do	...do	...do	No.	Yes.		
14	23	25	...do	...do	..do	...do	...do	No.	Yes.		
14	24	25	...do	...do	..do	...do	...do	No.	Yes.		
14	25	25	...do	...do	..do	...do	...do	No.	Yes.		
14	26	25	...do	...do	..do	...do	...do	No.	Yes.		
14	27	25	...do	...do	..do	...do	...do	No.	Yes.		
14	28	25	...do	...do	..do	...do	...do	No.	Yes.		
14	29	25	...do	...do	..do	...do	...do	No.	Yes.		
14	30	25	...do	...do	..do	...do	...do	No.	Yes.		
14	31	25	...do	...do	..do	...do	...do	No.	Yes.		
14	32	25	...do	...do	..do	...do	...do	No.	Yes.		
14	33	25	...do	...do	..do	...do	...do	No.	Yes.		
14	34	25	...do	...do	..do	...do	...do	No.	Yes.		
14	35	25	...do	...do	..do	...do	...do	No.	Yes.		
14	36	25	...do	...do	..do	...do	...do	No.	Yes.		
14	37	25	...do	...do	..do	...do	...do	No.	Yes.		
14	38	25	...do	...do	..do	...do	...do	No.	Yes.		
14	39	25	...do	...do	..do	...do	...do	No.	Yes.		
14	40	25	...do	...do	..do	...do	...do	No.	Yes.		
14	41	25	...do	...do	..do	...do	...do	No.	Yes.		
14	42	25	...do	...do	..do	...do	...do	No.	Yes.		
14	43	25	...do	...do	..do	...do	...do	No.	Yes.		
14	44	25	...do	...do	..do	...do	...do	No.	Yes.		
14	45	25	...do	...do	..do	...do	...do	No.	Yes.		

2.—SYNOPTICAL TRANSCRIPT OF NOTES FROM THE FIRING RECORD.

Russian life-saving rockets and stand.

Date.	No. of round.	
1879.		
Oct. 18	1	Italian hemp line No. 6. Line carried out 250 yards from firing point, when the rocket chain broke, freeing the rocket, which burst shortly afterwards. The fragments of the rocket and chain were found. The rear diaphragm, to which the rocket stick is attached, was found to have been blown out, the walls between the vents not being strong enough to withstand the pressure of the imprisoned gases. The ring of the rocket chain had a flaw in the material. The chain parted at that point. It is probable that the chain broke at the instant the composition took fire all around, giving a sudden increase of velocity.
18	2	Rocket exploded as before. Flight erratic; rocket ricocheted on the water before bursting.
18	3	Erratic trajectory. Rocket ricocheted on the water, turned to the right, *from* which direction the wind was blowing, and finally burst.
18	4	Struck the sand beach 60 yards from the stand, ricocheted and disappeared beneath the water.
20	5	Rocket exploded about 200 yards in front of stand. Used quick-match in the vents. Rocket shot out of tube almost the instant the port-fire was applied.
20	6	No remarks. By some mistake the record was left incomplete.
22	7	Exploded in the air. Time of flight, 4½ seconds.
22	8	Exploded in the air 2¼ seconds from time of starting.
22	9	Exploded in the air 4 seconds from time of starting.
22	10	Exploded in the air about 280 yards from the stand; time lost.
22	11	Exploded in the air; no time taken.
22	12	Exploded in 1¾ seconds from time of starting.
22	13	Exploded in 2 seconds from time of starting.
22	14	Exploded in the air; no time taken.
22	15	Did not explode. Good line shot. Ricocheted two or three times on the sand.
Nov. 14	16	Exploded in the air.
14	17	Exploded in the air.
14	18	Exploded in the air.
14	19	Exploded in the air.
14	20	Exploded in the air.
14	21	Exploded in the air.
14	22	Exploded in the air.
14	23	Exploded in the air.
14	24	Exploded in the air.
14	25	Rocket exploded in the air.
14	26	Rocket exploded in the air.
14	27	Rocket exploded in the air.
14	28	Rocket exploded in the air.
14	29	Rocket exploded in the air.
14	30	Rocket exploded in the air.
14	31	Rocket exploded in the air.
14	32	Rocket exploded in the air.
14	33	Rocket exploded in the air.
14	34	Rocket exploded in the air.
14	35	Rocket exploded in the air.
14	36	Rocket exploded in the air.
14	37	Rocket exploded in the air.
14	38	Rocket exploded in the air.
14	39	Rocket exploded in the air.
14	40	Rocket exploded in the air.
14	41	Rocket exploded in the air.
14	42	Rocket exploded in the air.
14	43	Rocket exploded in the air.
14	44	Rocket exploded in the air.
14	45	Rocket exploded in the air.

PART III.

GERMAN LIFE-SAVING ROCKETS AND ROCKET APPARATUS.

GERMAN LIFE-SAVING APPARATUS.

I.—5^{cm} GERMAN LIFE-SAVING ROCKET.

(Plate III.)

1.—DESCRIPTION.

The 5-centimeter German life-saving rocket (5^{cm} Rettungsrakete) is composed essentially of a body, head, base, rocket-stick and chain. The rocket case or body is cylindrical, made of sheet metal 0''.05 in thickness.

The head is ogival, with a shoulder that extends one-fourth of an inch beyond the case, and has a cylindrical tenon to fit the front end of the rocket case.

The latter is secured to the head by screws. The inside of the rear end of the case is reinforced for 1''.1 of its length by a cylindrical metallic ring, which serves as a seat for the screws that attach the base to the body.

The base extends to the rear, forming three ribs, placed triangularly, with all the metal removed from the axial portion to facilitate the escape of gas. These ribs conjoin at their posterior ends. An axial hole is drilled through this portion, having a female screw thread cut upon its interior surface to receive the screw on the end of the rocket stick.

When prepared and packed for service the composition is covered by a water-proof cap, from which projects a fuse, extending 2''.5 towards the rear. The fuse is steadied in its position by a strap of laboratory paper reaching to one of the ribs. The fuse and cap are covered with a coat of shellac varnish. Care must be taken in handling not to break off the fuse, which is more or less exposed.

The rocket-stick is of wood, enveloped at the front end by a metallic frustum of a cone, whose larger base receives the end of the stick, and whose smaller base is penetrated by the shank of a screw, intended to enter the hole in the base of the rocket. The stick, frustum, and screw-shank are bound together, and held in place by two wrought-iron bolts of small diameter.

The rear end of the rocket-stick is armed with an iron loop, with flattened arms, slightly curved to fit the outside of the stick. This loop serves as the point of connection for the rocket-chain.

The diameter of the rocket-stick is slightly greater in the middle than at either end.

All the metallic parts of this line-carrying projectile are painted black.

2.—Principal dimensions and weights.

	Inches.	Centimeters.
Total length of 5cm life-saving rocket	23.5	59.69
Case or body:		
Length	15.0	38.10
Exterior diameter	2.15	5.45
Interior diameter	2.05	5.20
Thickness of metal	0.05	0.13
Head:		
Total length	5.2	13.20
Point—		
Length of	3.6	91.44
Diameter of base	2.65	6.73
Tenon—		
Length	1.6	4.06
Diameter	2.05	5.20
Base-ring:		
Length	1.1	2.79
Exterior diameter	2.05	5.20
Interior diameter	1.65	4.19
Base:		
Total length	5.8	14.73
Diameter, front end	2.65	6.73
Diameter, rear end	1.25	3.17
Length, embracing case	0.9	2.28
Length of female screw in rear end	1.2	3.05
Diameter of screw hole	0.625	1.57
Depth of ribs at front end	0.45	1.14
Depth of ribs at rear end	0.40	1.01
Width of ribs	0.35	0.89
Number of ribs	Three	....
Rocket-stick:		
Total length	39.4	100.07
Diameter at junction with rocket	1.2	3.05
Diameter at larger base of frustum	2.2	5.58
Diameter at middle	2.2	5.58
Diameter at rear end	2.0	5.08
Rocket-chain:		
Total length	87.0	220.98
Ring—		
Exterior diameter	1.5	3.81
Interior diameter	0.7	1.78
Thickness	0.4	1.01
Links—		
Length	1.5	3.81
Width	0.75	1.90
Thickness	0.20	0.51
Total length of rocket and stick	61.7	156.71
	Pounds.	Kilos.
Weight of rocket	10.0	4.53
Weight of rocket stick and chain	5.5	2.49
Total weight of rocket complete	15.5	7.02

For further details, see Plate III.

II.—8^{cm} German Life-saving Rocket.

(Plate IV.)

1.—DESCRIPTION.

The form and construction of this life-saving rocket (8^{cm} Rettungsrakete) is essentially the same as the 5-centimeter rocket, from which it differs only in dimensions and weight. The description of the 5^{cm} rocket will answer for this one.

2.—Principal dimensions and weights.

	Inches.	Centimeters.
Total length of 8^{cm} life-saving rocket	34.5	87.63
Case or body:		
Length	10.5	26.67
Exterior diameter	3.22	8.17
Interior diameter	3.1	7.87
Thickness of metal	0.06	0.15
Head:		
Total length	8.75	22.21
Point—		
Length	7.25	18.40
Diameter of base	3.75	9.51
Tenon—		
Length	1.5	3.81
Diameter	3.1	7.87
Base-ring:		
Length	1.35	3.42
Exterior diameter	3.1	7.87
Interior diameter	2.875	7.29
Base:		
Total length	8.3	21.08
Diameter of front end	3.75	9.51
Diameter of rear end	1.50	3.81
Length, embracing case	1.8	4.57
Length of female screw in rear end	1.6	4.06
Diameter of screw-hole	0.625	1.58
Depth of ribs at front end	0.75	1.90
Depth of ribs at rear end	0.875	2.21
Width of ribs	0.75	1.90
Number of ribs	Three	
Rocket-stick:		
Total length	39.9	101.34
Diameter at junction with rocket	1.4	3.55
Diameter at larger base of frustum	2.0	5.08
Diameter at middle	2.3	5.84
Diameter at rear end	2.3	5.84
Rocket-chain:		
Total length	122.5	310.64
Ring—		
Exterior diameter	1.7	4.31
Interior diameter	1.1	2.79
Thickness	0.3	0.76
Links—		
Length	1.3	3.30
Width	0.6	1.52
Thickness	0.2	.50
Total length of rocket and stick	73.3	186.18
	Pounds.	Kilos.
Weight of rocket	35.0	15.98
Weight of rocket stick and chain	7.25	3.29
Total weight of rocket complete	42.25	19.27

For other details see Plate IV.

III.—8^{cm} German anchor rocket.

(Plate V.)

1.—DESCRIPTION.

The 8-centimeter anchor rocket (8^{cm} Ankerrakete) for life-saving purposes is composed of a body, anchor-head, base, rocket stick and chain.

The case, or rocket-body, is made of sheet-metal, 0''.06 in thickness.

The anchor-head is made of iron. The front end is sub-spherical in form, connected with the convex curves of the arms by re-entrant tangent-curved surfaces.

The short shank in rear of the head forms a cylindrical tenon that fits the front end of the rocket case, to which it is secured by screws.

The arms and flukes are four in number. The former are triangular-prismoidal in outline, and are placed at right angles to each other.

The arms are furnished with the usual palmate flukes, which are well adapted for "holding."

The rear end of the rocket case is reinforced on the inside for 1''.5 of its length by a cylindrical iron ring. The latter furnishes a seat into which the screws that attach the base are turned.

The base is tripodal in form, the legs joining a cylindrical ring at the front end. The conjunction of the legs, or ribs, at the rear end forms a seat into which is screwed the rocket stick.

When prepared for use and ready for packing the rocket case is filled with composition and the rear end of the case closed with a water-proof cap to protect the contents from the effects of moisture.

This cap is placed 1''.3 towards the front from the rear edge of the basal ring. A fuse, 2''.7 in length and 0''.5 in diameter, passes through the cap and connects with the rocket composition.

The projecting fuse is liable to be broken off in handling, if great care is not exercised, as the operator will involuntarily thrust his hand between the ribs to grasp the rocket in picking it up or carrying it.

The fuse is steadied in its position by a strap of laboratory paper attached to one of the ribs in the same manner as in the 5^{cm} rocket.

The fuse is coated with shellac varnish.

The rocket *stick*, technically so called, is in this case a hollow cylindrical tube of sheet metal, with a diameter about equal to that of the wooden stick for the 8^{cm} life-saving rocket.

It is constructed by taking a strip of sheet metal of the necessary length and width, curving it and fastening the edges together with twenty-three iron rivets.

The front end is filled with an iron plug extended to the front as a frustum of a cone, 1''.125 in altitude, from which projects the male screw, 2''.25 long, that enters the base of the rocket when assembled for use. The rear end is furnished with an iron loop having flattened arms that are riveted to the tube. This loop serves as the point of attachment for the rocket-chain.

The rocket-chain is made of the best wrought iron.

The rocket case, base, and "stick" form the *shank* of the quadripalmate anchor.

The usual anchor *stock* is absent in this combination.

The anchor rocket, rocket-stick, and chain are all painted black.

2.—*Principal dimensions and weights.*

	Inches.	Centimeters.
Total length of 8^{cm} anchor rocket	33.15	84.19
Rocket-case:		
Length	20.15	51.17
Exterior diameter	3.22	8.17
Interior diameter	3.1	7.87
Thickness of metal	0.06	0.15
Anchor-head:		
Total length	6.5	16.51
Diameter, excluding arms	3.35	8.50
Length of tenon-shank	1.85	4.69
Diameter of tenon-shank	3.1	7.87
Arms—		
Depth near shank	1.4	3.55
Width under side near shank	1.2	3.04
Depth near fluke	0.8	2.03
Width under side near fluke	0.8	2.03
Number of	Four	
Distance from front end of head to rear edge of arm*	4.65	11.80
Distance from front end of head to point of fluke*	7.55	19.17
Spread of flukes	15.5	39.36
Length of palms	3.75	9.51
Width of palms	3.75	9.51
Base-ring:		
Length	1.5	3.81
Exterior diameter	3.1	7.87
Interior diameter	2.87	7.28
Base:		
Total length	9.4	23.87
Diameter, front end	3.75	9.51
Diameter, rear end	1.8	4.57
Length of, embracing case	1.4	3.55
Length of female-screw thread	2.0	5.08
Diameter of same	0.875	2.21
Depth of ribs, front end	6.75	1.90
Depth of ribs, rear end	0.80	2.03
Width of ribs	0.40	1.01
Number of ribs	Three	
Rocket-stick:		
Total length	39.375	99.98
Length of screw	2.25	5.71
Diameter of screw	0.875	2.21
Number of rivets	23.0	58.41
Rocket-chain:		
Total length	123.0	312.41
Ring—		
Exterior diameter	1.5	3.81
Interior diameter	0.7	1.77
Thickness	0.4	1.01
Links—		
Length	1.5	3.81
Width	0.75	1.90
Thickness	0.20	0.50
Total length of rocket and stick	70.275	178.47
	Pounds.	Kilos.
Average weight of anchor rocket	37.375	16.95
Average weight of rocket stick and chain	9.0	4.08
Total weight of anchor rocket complete	46.375	21.03

* Measured parallel to the axis of the rocket.

See Plate V for other dimensions.

IV.—German life-saving rocket-stand.

(Plate VI.)

1.—Description.

The German rocket-stand is trough-like in shape, and is supported by two legs near the front end and a curved iron foot or tang at the rear end.

The general outline may be seen by reference to the plate, Figs. 1 to 6.

The trough-like body of the tube is made of sheet iron or steel, and is constructed from a single piece of metal, curved over a former of the required shape.

A longitudinal slot in the bottom, 10″.9 long and 1″ wide, extends from the front end to the first exterior rib (Fig. 2). This slot is for the reception of the rocket-chain, which is led along the bottom of the trough under the rocket and stick, and allowed to pass downward through this slot.

The longitudinal edges of the trough are stiffened and strengthened by angle-pieces of iron running the whole length. These angle-pieces have one side riveted to the inside of the trough, forming the bearing surfaces for the rockets, and the other forming an exterior projecting flange.

A rolled iron bar, 1″ wide and 0″.3 thick, runs from the rear end of the longitudinal slot the whole length of the trough on the under side.

The lower or rear end of this metallic bar projects about 10″. beyond the frame, is decurved and pointed, to form the claw or tang for the support of this end of the trough.

A curved brass plate, 0″.7 wide and 0″.3 thick, arches over the rear end of the frame, forming an abutting surface for the rocket-stick and binding the sides of the trough together.

Two six-inch braces, 0″.7 wide, extend backwards and downwards to the tang from the junctions of the brass plate with the sides of the trough.

The angle-pieces, bottom bar, brass plate, and braces give strength and rigidity to the rocket-stand.

The stand is further strengthened by four nearly equi-distant exterior iron ribs, 1″ wide, that serve to bind the component parts together.

On the under side, below the first rib, is a lug which supports a horizontal axis.

The ends of this axis are slotted to receive the ends of the legs. The latter are held in position by metallic pins passing through their blade-like ends and the axis.

These projections from the legs are trapezoidal, the beveled ends abutting against side plates on the exterior of the trough when the stand is in use.

The side plates prevent the indentation of the thin metal of the trough by the upper ends of the legs.

The legs are of wood, ferruled with iron at each extremity to prevent splitting.

Decurved iron spikes in the lower ends enable them to be placed firmly in the hard or frozen soil to give stability to the stand.

The legs can be closed together and then folded to the rear until they lie parallel to the axis of the trough.

Notwithstanding the angle-irons, the longitudinal slot at the front end weakens the trough considerably; to remedy this, side plates, 10″.6 long, are placed one on each side under the forward rib to stiffen the sides.

The draughtsman has erred slightly in outlining the cross-section of the trough in Plate VI. As shown there it is nearly semi-circular in form, while it should have appeared almost trapezoidal with a rounded bottom.

The planes of the projecting flanges are represented as being coincident, whereas they should bend downwards slightly, forming an obtuse angle with each other. This rocket-stand is painted a lead-color.

2.—Principal dimensions and weight.

	Inches.	Centimeters.
Trough:		
Total length	72.75	184.78
Total length with rear tang	82.75	210.18
Interior width at top	3.8	9.65
Interior width at bottom	1.0	2.54
Inside slant height of sides	2.8	7.11
Length of slot at front end	10.9	27.68
Width of slot at front end	1.0	2.54
Exterior ribs—		
Number of	Four	
Width	1.0	2.54
Distance of horizontal axis from front end	15.5	39.36
Two legs:		
Total length	54.375	138.10
Diameter of upper end	1.3	3.30
Diameter of lower end	1.3	3.30
Length of spike in lower end	3.0	7.62
	Pounds.	Kilos.
Weight of rocket-stand	35.0	15.98

For further particulars consult the drawings, Plate VI.

V.—FIRING-STAFF.

(Plate VI, Fig. 7.)

1.—DESCRIPTION.

This is made of wood, shod at one end with a sharp-pointed steel socket and armed at the other with a hollow brass tube, bent and split to form a hinged clamp. The latter is actuated by a lever and spring.

This staff is used to hold the *pillenlichte* for igniting the rocket fuse.

The sharp-pointed socket is for convenience in thrusting it into the ground in an upright position.

If carelessly thrown aside, it is liable to be lost in the sand. The staff is painted the same color as the rocket stand.

The drawing shows a *pillenlicht in situ*.

2.—Dimensions and weight.

	Inches.	Centimeters.
Total length	72.0	182.88
Diameter	1.2	3.04
Length of pointed socket	10.0	25.40
	Pounds.	Kilograms.
Weight	2	0.91

VI.—FIRING-LOCK.

(Plate VII, Figs. 1–4.)

1.—DESCRIPTION.

The firing-lock, or more properly the igniting-lock (Zündschloss), is an instrument used for the purpose of igniting the primer in the end of the *pillenlicht* by percussion.

The principal components are the stock, lock tube, firing-bolt, bolt-spring, bolt-pin, firing-pin, firing-lever, and spring.

2.—STOCK.

The stock is made of hard wood, neatly finished. The lock-tube is attached to the front end of the stock, on the under side of which is a curved projection to give a firm grip to the hand of the operator.

A hole is sometimes bored through the butt of the stock, through which a cord is passed for the purpose of attaching it to the belt of the surfman or to his wrist in order to prevent its loss.

3.— LOCK-TUBE.

This is made of bronze (gun metal), carefully turned and finished upon the exterior. The middle portion of the tube is cylindrical, expanding at the front end.

The rear portion is also cylindrical, greater in diameter than the middle part, to which it is joined by a projecting molding. This molding is slotted longitudinally on top to form a fulcrum seat for the firing lever.

The front end is countersunk to form a cavity whose interior surface is somewhat bell-mouthed in shape.

An axial hole is bored from the rear end nearly to the anterior cavity, and a small hole for the firing-pin is drilled through to connect the two. The large hole is counterbored to within 0″.8 of the bottom in order to increase its diameter for the reception of the body of the firing-bolt and its spiral spring.

A transverse slot, with circular ends, extends through the tube from side to side to allow longitudinal play for the bolt-pin in cocking and firing.

On top of the tube, directly over the middle point of the transverse slot, is a square mortise through which the bolt-catch on the firing-lever passes.

A hole is drilled in the upper part of the molding for the fulcrum-pin of the firing-lever, and another near the rear end for the assembling-pin that holds the tube and stock together.

4.—FIRING-BOLT.

The firing-bolt is cylindrical, with a round tenon in front of the body. The tenon fits closely the hole in the tube below the counterbore, and is armed at its front end with a needle or firing-pin.

A transverse hole through the body receives the bolt-pin of steel wire which projects on each side of the tube.

The bolt is actuated by a spiral spring of steel wire. The spring is placed between the bolt-head and a plug that fills the rear portion of the axial hole.

The firing-pin or needle is made of steel wire driven into a hole in the front end of the bolt and then brought to a very sharp point.

5.—FIRING-LEVER.

The firing-lever is made of steel and tempered. The rear end is flattened and bent slightly upwards to serve as a trigger.

At the front end is a rectangular bolt-catch projecting at right angles from the under side of the lever.

A flat steel spring under the rear end of the lever presses that end upwards and holds the bolt-catch down on the bolt. This catch passes through the mortise in the tube.

6.—*Principal dimensions and weight.*

	Inches.	Centimeters.
Total length of firing-lock	9.4	23.87
Length of lock-tube	5.75	14.59
	Ounces.	Grams.
Weight of firing-lock	11.25	318.93

7.—ACTION.

Seize the stock in the right hand, and with the thumb and index finger of the left compress the spiral bolt-spring by pulling the transverse bolt-pin A (Plate VII) to the rear until the bolt-catch I drops off the body of the bolt B, and falls upon the tenon C.

The spring S will press up the rear end of the firing-lever T and keep the bolt-catch in place.

The annular shoulder of the bolt presses against the rear surface of the catch. In this position the firing-pin D, or needle, is withdrawn into the lock-tube, as shown in Fig. 3. The pressure of the thumb of the right hand upon the flattened end T (Fig. 2) of the lever compresses the spring S (Fig. 3), elevates the bolt-catch I (Fig. 3), to the position I (Fig. 4), releases the bolt, and allows the spiral spring F (Fig. 3) to act.

The bolt springs forward, thrusting the firing-pin D out into the cavity E, where it strikes the fulminate in the end of the *pillenlicht* P and ignites the composition.

8.—USE.

The object of the firing-lock is to furnish a ready means of igniting *pillenlichte* after they are inserted in the firing-staff and clamped.

VII.—PILLENLICHTE.

(Plate VII, Fig. 5.)

1.—DESCRIPTION.

These are short cylindrical tubes of laboratory paper, filled with a composition resembling that in port-fires. The exact ingredients and and their proportions are unknown.

A countersink is formed in one end, at the bottom of which is placed a small disk of fulminate covered with a water-proof cap. The entire exterior is varnished.

A section of a *pillenlicht* is shown at P (Fig. 4, Plate VII). These are used to light the fuses of the life-saving and anchor rockets.

The *pillenlichte* are put up in packages of twenty (20) each.

2.—*Dimensions and weight.*

	Inches.	Centimeters.
Total length	1.55	3.93
Exterior diameter	0.625	1.58
Depth of countersink in end	0.1	0.25
	Seconds.	
Time of burning	45	....
	Grains.	
Weight	230	....

VIII.—PACKING.

LIFE-SAVING ROCKETS.

1.—DESCRIPTION.

The German anchor and life-saving rockets are packed securely in tin-lined boxes. The boxes are made of hard pine, planed smooth on both sides, with the corners dovetailed. The bottom, sides, and ends are lined with tin. The top is not lined and is screwed to the sides and ends. A label on the inside of the cover of the box bears printed on its face a list of the contents of the box in the German language. A similar label is pasted on the end of the box. The rocket boxes are oiled but not painted. Bottom, middle, and top clamps at each end hold the rockets in place. A strip of felt separates the rockets from the clamps.

2.—DIMENSIONS OF PACKING-BOXES.

a.—For 5^{cm} *life-saving rockets.*

		Inches.	Centimeters.
Exterior dimensions	Length	26.75	67.93
	Width	9.5	24.13
	Depth	8.125	20.57
Number of rockets in each box			Four.

b.—For 8^{cm} *life-saving rockets.*

		Inches.	Centimeters.
Exterior dimensions	Length	37.25	94.10
	Width	12.5	31.74
	Depth	11.25	28.56
Number of rockets in each box			Four.

c.—For 8^{cm} *anchor-rockets.*

		Inches.	Centimeters.
Exterior dimensions	Length	36.0	91.44
	Width	14.25	36.18
	Depth	20.5	52.06
Number of anchor-rockets in each box			Two.

3.—WEIGHTS.

	Pounds.	Kilogrammes.
Total weight of packing-box containing four 5^{cm} rockets	61.5	27.88
Total weight of packing-box containing four 8^{cm} rockets	195.5	88.67
Total weight of packing-box containing two 8^{cm} anchor-rockets	151.0	68.40

4.—ROCKET-STANDS.

The German rocket stands are packed in long narrow boxes, painted a lead color. The top is screwed to the sides and ends. Rope loops,

two on each side near the ends serve as handles for transportation. A firing-staff is placed in each box.

a.—Dimensions and weight.

		Inches.	Centimeters.
Exterior dimensions..	Length	86.0	218.44
	Width	8.0	20.32
	Depth	7.25	18.40
		Pounds.	Kilos.
Total weight of box with stand and staff		81.5	36.90

5.—ROCKET STICKS AND CHAINS.

1.—DESCRIPTION.

The sticks and chains for the 5-centimeter and 8-centimeter rockets are tied in bundles of 4 each.

The chains are doubled back and forth the length of the stick, and have the loops fastened to the ends of the stick by twine.

The anchor-rocket sticks are placed in bundles of two each.

2.—WEIGHTS OF BUNDLES.

	Pounds.	Kilogrammes
For 5^{cm} rockets, 4 sticks and chains	22.25	10.08
For 8^{cm} rockets, 4 sticks and chains	29.0	13.15
For 8^{cm} anchor-rockets, 2 sticks and chains	18.0	8.16

IX.—DATE OF MANUFACTURE.

All the German life-saving rockets, 5-centimeter, 8-centimeter, and 8-centimeter anchor-rockets were fabricated in 1877. The rockets were packed in December, 1877, as shown by the labels.

X.—GERMAN ROCKET-LINE.

This rocket line is made of hemp. The line is twisted, and is made with three strands, each composed of four yarns. The diameter of this line is 0″.31, or a little greater than "No. 9 Silver Lake braided cord." The rocket-line is stowed in the faking-box in the usual manner. The combined weight of the faking box and line is 100 pounds, or 9.5 pounds greater than the United States service box A, with a No. 9 linen line.

XI.—GERMAN FAKING-BOX.

(Plate VIII.)

1.—DESCRIPTION.

These boxes contain the rocket-lines, and are similar to those in use in our own service. They differ from the American box in being longer, a little less in width, and far more complicated in construction.

The top has three equidistant transverse cleats on the upper side to strengthen it. A lip at each end overhangs the end of the box. Iron straps attached to the lid and run inside of the box form the hinges. These hinges are held in position and swing upon iron pins 5''.875 in length, having an eye at one end and a slot at the other. A leather thong is made fast in the eye-hole, and is long enough to pass through the slot in the other end of the pin. This pin is thrust through the cylindrical heads of the hinge straps on the box and lid, and the thong is passed through the slot to secure the pin in position. This arrangement admits of the top or lid being removed entirely when desired. Two slotted straps or hasps attached to the front side of the lid engages the staples on the front of the box. The body of the box is rectangular in shape, open at the top and bottom, and of sufficient depth to contain the faking-pins and line.

The staples on the front side of the box are seated upon iron plates 2'' × 1''.5. The plates are let into the wood a distance equal to their thickness, and are held in place by four short screws, one at each angle or corner. The handles are placed at the ends of the box near the upper edge. These are of one-fourth inch iron wire, bent to the required form, and passed through staples attached to thin iron plates 4''.5 × 2''.125 screwed to the box. Near the lower edges of the ends, midway between the sides, are two plates carrying the iron hooks that engage corresponding staples on the frame and attach the box to the frame.

The frame is made of 1''.25 lumber, and is 46''.5 in length by 17''.375 in width. The width of the side and end pieces is 4''.5. Holes are bored and tapped to fit the screw-thread tenons of the faking-pins in both the side and end pieces. There are sixteen pins on each side and four at each end—forty in all. The false bottom is pierced with holes corresponding to the number of faking-pins, and is placed over them, resting upon the frame.

The corners of the body of the box are covered with sheet-iron angle-pieces. The corners of the lid are similarly protected.

The total weight of the faking-box and rocket-line is 100 pounds. The faking-box is made of hard pine, and painted lead color.

For further details and dimensions, see Plate VIII.

XII.—Method of using the German rocket apparatus.

The apparatus is supposed to be at the firing-point. First remove the rocket-stand from its box, spread the legs, and place the stand with the axis of the trough pointing in the desired direction. Then give the proper elevation by raising or lowering the front end by means of the legs.

A quadrant or combination level is used to adjust the elevation. Place the faking-box several feet in front of the stand, turn it upside down, remove the frame and pins and false bottom. Incline the box to the front with its length in the direction of the line of fire, and place the false bottom or frame transversely on edge beneath the rear end of the box, to preserve the proper inclination towards the front. Then screw a rocket-stick into the base of one of the rockets, put the chain in the slot at the front end of the trough of the stand, and lead it along the bottom of the trough. Place the rocket in the trough over the chain, drawing the latter taut, and allow the end of the stick to abut against the plate at the lower end of the trough; carry the other end of the rocket-chain to the front and tie the rocket-line to the ring. The rocket is now ready to be fired.

Take a *pillenlicht* and put the square end in the clamp of the firing-staff, which brings the end with the fulminating primer to the front. Next place the bell-shaped mouth of the firing-lock, with the firing-pin withdrawn, over the outer end of the *pillenlicht*; press the thumb upon the rear end of the firing-lever. This action relieves the firing-pin, the spiral spring throws it to the front, exploding the primer, which sets the composition on fire. Approach the rocket-stand, extend the firing-staff until the burning *pillenlicht* comes in contact with and ignites the fuse in the base of the rocket. After seeing that the fuse is properly ignited, stand clear of the apparatus.

XIII.—ACTION.

As soon as the fuse burns up to the base of the rocket, the composition takes fire, and the rocket, guided by the inclined trough of the stand, is launched to the front, carrying with it the stick, chain, and rocket-line. The object of the stick is to give steadiness to the flight, that of the chain to preserve the line from being burned off by the flames issuing from the rocket.

XIV.—*Cost of German life-saving apparatus* (1875).

Articles.	Cost.	
	German reichs-marks.	United States dollars.
Life-saving rocket (8 centimeter) carrying line 1,400 feet	24.20	5.808
Life-saving rocket (5 centimeter ?) carrying line 1,000 feet	15.00	3.60
Anchor-rocket, 1,400 feet	101.00	24.24
One shot-line, 1,600 to 1,700 feet long (extra made)	60.00 70.00	14.40 16.80
Double hauling-line	113.00	27.12
Large hawser, 1,000 feet long	216.00	51.84
Tongs or nippers for holding cartridge	6.00	1.44
Pistol for firing cartridge (firing-lock)	6.66 7.50	1.5984 1.80
Quadrant	9.90	2.376
Iron support (or tripod) for rockets	40.00	9.60
Box for shot-line (each)	36.00	8.64

The whole rocket apparatus, placed upon one wagon, with all necessary appurtenances except rockets, costs 4,400 marks = $1,056. Complete double wagon, with appurtenances, costs 3,730 marks = $895.20.

There are three reserve faking-boxes for each rocket apparatus.

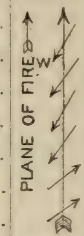
(N. B.—One German reichsmark = 24 cents, gold.)

XV.—EXPERIMENTS WITH GERMAN LIFE-SAVING ROCKETS.

EXPERIMENTS WITH LIFE-SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

1.—*Record of firings with German life-saving and anchor rockets and apparatus.*

Date.	Number of fire.	Elevation.	Kind of rocket-stand.	Life-saving rocket.				With what fired.	Shot-line.				Range.	Deviation of rocket, right or left.	Drift of shot-line at 300-yard stake.	Wind.	
				Caliber, centimeters.	Kind.	Weight.	Total weight, rocket, stick, and chain.		Material.	Number of line.	Length.	Action.				Direction.	Velocity, miles per hour.
1879.		°				*Lbs.*	*Lbs.*				*Yds.*		*Yards.*	*Feet.*	*Feet.*		
Oct. 18	1	32.5	German...	5	German...	10	15.5	Port-fire, Eng.	Dark linen...	4	700	Good	404	87 R.	56 R.		15.0
18	2	31	....do	5	....do	10	15.5	....do	Linen, W. P...	4½	700	....do	402⅓	103 L.	99 L.		15.0
18	3	31	....do	8	....do	35	42.25	....do	....do	6	600	Broken	....	Left.	Left.		11.0
18	4	31	....do	8	....do	35	42.25	....do	....do	6	600	Good	545⅔	103 L.	88 L.		16.0
20	5	31.5	....do	8	Anchor ...	37	46	Pillenlicht	Italian hemp..	9	600	Tangled and cut.	....	....	......		12 to 8
20	6	31	....do	8	....do	37.75	46.75	....do	Linen.........	10	600	Good	350 to 400	Estimated.	......		12 to 8



NOTE.—The shot-lines used were the Silver Lake Company's braided lines.
Abbreviations: R = right; L = left; W. P. = water-proof.

2.—SYNOPTICAL TRANSCRIPT OF NOTES FROM THE FIRING-RECORD.

German life-saving and anchor-rockets and stand.

Date.	No. of round.	
1879.		
Oct. 18	1	Service faking-box used and placed 2 feet to right of stand, and to the rear nearly the length of the rocket-chain. Action of rocket, good.
18	2	Same remark. A larger line used.
18	3	8^{cm} rocket. Line broke. It is quite probable that the line in vibrating struck a sharp corner on the stand and was cut off, as the faking-box was placed to the right and rear as in the preceding shots. An examination of the frayed ends of the line gave no definite solution of the manner of severance. Spent rocket recovered about 900 yards from the firing point.
18	4	8^{cm} rocket. Used same line as before. Action of rocket, good.
20	5	8^{cm} anchor-rocket. Fired out to sea. No. 9 line in loose coils as wound up around hand and elbow. Coils got caught and were carried out to sea in large bunches. The line was cut by drawing through a tangled knot. Range about 250 to 300 yards, estimated—a low estimate. Range much diminished by increased resistance of air due to the large "bunches" in the line.
20	6	8^{cm} anchor-rocket. Fired out to sea. Used No. 10 linen line (Silver Lake), which was fired from the original coil. The line ran out well. In hauling in on the line it was estimated that the anchor slipped about 60 feet before it caught in the bottom and held. Life-boat of Station No. 1, District 4, New Jersey, was launched and hauled out to the anchor by the rocket-line. The anchor-rocket was hoisted into the boat and the latter hauled nearly to the shore by the line. The sea-water left the line stiff and difficult to handle; it could not be coiled easily.

NOTE.—In the German method of using the apparatus the rocket-chain is laid along the bottom of the trough of the stand under the rocket, and then, falling downward, is lead to the front, where the faking-box and line are placed. In the above trials the box was placed to the rear and a little to one side, to see whether the stand interfered with the running out of the line. In this iustance the chain had to be led to the rear.

PART IV.

ENGLISH LIFE-SAVING ROCKET APPARATUS.

ENGLISH LIFE-SAVING APPARATUS.

I.—ENGLISH LIFE-SAVING ROCKET.

(Plate IX.)

1.—DESCRIPTION.

The 12-pounder rocket used by the English coast-guard service is the invention of Colonel (since General) Boxer, R. A. Three different patterns of these rockets have been made and issued. The one now in use is known as "Mark III."

The Boxer rocket is composed of a head, head-clip, body, base-clip, base-plug, and diaphragm.

The head is hemispherical in form, with a cylindrical tenon that fits in the front end of the rocket-case.

The head-clip nearly envelops the front end of the rocket-case, with its forward edge coincident with the exterior junction of the case and head. On one side of the case the iron strap forming the head-clip is bent outwards to form a short rectangular tube, whose axis is parallel to that of the rocket.

This short tube receives the front end of the rocket-stick.

The body of this rocket consists of two cylinders of sheet metal (Bes-

senier). These cylinders are placed end to end with their axes coincident with the same straight line. The front cylinder is shorter than the other, to which and the inner diaphragm it is joined by screws passing through cases into the diaphragm.

The front cylinder is filled with rocket composition to within 0″.4 of its front end. A conical-shaped cavity is left in the axial portion to furnish a large surface of inflammation.

The rear cylinder is filled in a similar manner with composition, leaving a solid portion of this composition at the front end between the two cavities 1″.2 in thickness. The cavity or "bore" of the rear cylinder is also conical in shape. The base-clip is analogous to that at the head, but is longer. It nearly surrounds the rear end of the rocket and has a rectangular tubular projection on one side in line with that of the head-clip. The base-plug closes the rear end of the cylinder and is pierced with an axial vent one inch in diameter, through which the gas escapes after the ignition of the composition.

The diaphragm is placed between and inside of the two body cylinders and performs the same functions for the front cylinder that the base plug does for the rear one, and in addition serves as a seat for the assembling-screws. A paper cap covers the vent, which must be broken before firing.

The rocket-cases are protected on the inside from the action of the composition by a coat of anti-corrosive paint; the outside is protected and blackened by burning off oil. Since 1870 the exterior of the case is still further protected by two coats of red paint.

2.—Dimensions and weight.

Boxer rocket.

			Inches.	Centimeters.
Total length			25.0	63.50
Radius of head			1.5	3.81
Diameter of rocket case	Exterior		2.75	6.98
	Interior		2.6	6.6
Length of front cylinder			9.3	23.62
Length of rear cylinder			14.2	36.06
Head-clip	Length		1.5	3.81
	Rectangular projection	Width	1.3	3.30
		Depth	1.2	3.05
Base-clip	Length		2.5	6.35
	Rectangular projection	Width	1.5	3.81
		Depth	1.3	3.30
Length of clip-pin			*0.85	2.15
Diameter of vent			1.0	2.54
			Pounds.	Kilograms.
Weight of rocket			14.25	= 6.46

* Length of clip-pin before bending, 1″.2. Size of wire, No. 8 Birmington wire-gauge.

II.—Packing.

The Boxer rockets are packed in rough lumber boxes containing six rockets each. The boxes are not painted.

III.—Date of manufacture.

The rockets presented for trial were made in 1877 and had the stamp of the Royal laboratory at Woolwich on the packing-boxes.

IV.—PAINTS.*

Red for outside of case of Boxer life-saving rocket.

	Pounds.	Ounces.
Lead, red	3	0
Lead, white	1	0
Litharge	0	4
Copperas	0	2
Oil, linseed, boiled	1 pint.	

Anti-corrosive paint for inside of Boxer life-saving rocket cases.

Copal varnish, pints	0.25
Gold size, pints	1.0
Turpentine, spirits, pints	1.25
Lead, white, dry, pounds	7.0

V.—ROCKET-STICKS.

(Plate IX, Fig. 5.)

1.—DESCRIPTION.

These are made of pine and are 9 feet 6 inches in length. The portion of the stick that extends through the clips along one side of the rocket is square in cross-section with a groove on the side next to the rocket to fit the curvature of the case. The stick in rear of the rocket is octagonal in cross-section. The lower end of the stick is surrounded by an iron ferrule.

Two plates are placed, one at the upper end of the stick and the other at a distance from that end equal to the distance between the clips on the rocket. The lower plate has a small flange that brings up against the lower clip when the stick is inserted in position for firing; both plates are hollowed to fit the rocket-case.

An iron clip-pin with the head bent at right angles is inserted in a hole through the stick in front of the base-clip, to prevent the withdrawal of the stick in firing.

The stick is partially surrounded for 18″ below the vent by a sheathing of tin to protect it from the burning gases.

Axial holes are bored in each end of the stick for the attachment of the line. These holes are curved outward from the axis until they reach the exterior of the stick on the same side. The holes are smoothed by passing a red-hot iron through them, charring the wood. The sticks are unpainted, and are packed in bundles of six (6) each.

2.—DIMENSIONS AND WEIGHTS.

	Inches.	Centimeters.
Length (9′ 6″)	114.0	289.55
Width	1.25	3.17
Thickness	1.25	3.17
Number in a bundle	Six.	....
	Pounds.	Kilos.
Average weight of stick	3.16+	1.43
Average weight of each bundle	19 to 19.5	=8.61 to 8.73

* These were obtained from "Treatise on Ammunition, 1874," by Maj. W. R. Barlow, R. A., p. 298.

VI.—WASHERS.

Two kinds of washers are furnished with the Boxer rockets, brass and vulcanized India rubber. In firing, these are placed between the knot on the end of the rocket-line and the front end of the stick. The object of the washers is "to reduce the effect of the sudden jerk which is given to the line when the rocket is fired."

1.—DIMENSIONS.

		Inches.	Centimeters.
a. Brass washer	Diameter	1.0	2.54
	Thickness	0.15	0.38
	Diameter of hole in center	0.5	1.27
b. Rubber washer	Diameter	1.0	2.54
	Thickness	0.7	1.78
	Diameter of hole in center	0.5	1.27

VII.—ENGLISH LIFE-SAVING ROCKET-STAND.

(Plate X.)

1.—DESCRIPTION.

This stand is known as the Boxer rocket machine or stand, "Mark IV." The material is sheet-iron, except the legs, which are of wood. This stand is lighter and simpler in construction than the older forms.

The principal parts are an open rectangular trough or body, a curved trough, called by the English "a pry-pole," a horizontal axis, two legs, and a graduated arc made of brass.

The rectangular trough or body receives the rocket. Its width is less than its depth. The front end is stiffened by a narrow iron strap around the outside. The upper edges are rolled over wire for the same purpose. Near the rear end, on each side, are cut subelliptical holes to admit the port-fire in firing the rocket.

The body and pry-pole are connected by pieces of wrought iron, rivets, and braces. There are two of the latter, one on each side. Two pieces of wrought iron project from the rear end of the rectangular trough and have holes bored to receive the horizontal transverse axis.

The long rounded trough or pry-pole extends into the rear end of the body for a short distance. The upper edges of the pry-pole are rolled over a large wire to stiffen them, and the trough is still further strengthened by a wrought-iron bar 0″.5 thick, running along the bottom the whole length.

The lower or rear end of this bar is decurved and pointed to form a ground spike or foot. A strap with a buckle on the end is riveted to the pry-pole near the rear end, for the purpose of binding the legs to the pry-pole when they are folded up for transportation.

The horizontal axis has a small swinging tablet below, through which are pierced two holes for rivets for the legs. The latter have a lateral motion upon these rivets as axes.

The legs are made of tough wood. They have wrought-iron heads or sockets with slotted projections to embrace the tablet pendant from the horizontal axis. Ferrules envelop the lower ends, which are armed

with pointed spikes in order to secure a firm hold in the soil when placed in position.

On the right-hand side of the body, between the opening and the front end, is placed a sheet-brass quadrant (Fig. 2), graduated and marked from 0° to 35°. The limits of elevation that can be obtained with this stand, due to its construction, are from 17°.5 to 40°. At the center of this arc is a rivet with a projecting head, around which is fastened a short string with a minute pear-shaped plumb-bob dependent.

On the left-hand side of the body trough and parallel to its axis are the words "Life-Saving Apparatus," painted in white letters.

On the projection for the horizontal axis on the same side are painted the characters "IV," that designate the model of the stand.

Near the head of one of the legs is the date of fabrication, "1873."

The whole stand is painted lead color.

The rocket-stand is packed for transportation in a long, narrow box, made of rough lumber.

The contents of the box are marked upon the exterior.

2.—DIMENSIONS AND WEIGHTS.

			Inches.	Centimeters.
Total length of stand			116.0	294.63
Body	Length		27.75	70.45
	Width	Exterior	3.5	8.89
		Interior	3.	7.62
	Depth	Exterior	4.	10.16
		Interior	3.875	9.82
	Length of rear projections		1.7	4.32
	Size of openings in sides	Length	4.4	11.17
		Width	2.4	6.09
	Distance of front end of opening from rear end		7.25	18.41
	Distance from lower edge of opening to bottom		0.8	4.57
	Distance pry-pole inserted from rear end		7.25	18.41
	Distance between bottom of pry pole and bottom of body		2.7	6.86
Pry-pole	Length		95.5	241.42
	Interior width		1.5	3.81
	Depth	Exterior	2.	5.08
		Greatest interior	1.5	3.81
	Length of chord of ground-spike		3.0	7.62
	Distance of strap and buckle from rear end		46.0	116.84
Axis and tablet	Length		3.5	8.89
	Depth		2.6	6.6
Legs	Total length		61.125	155.24
	Length of slotted projection		2.0	5.08
	Diameter of socket	Upper end	1.0	2.54
		Lower end	1.4	3.55
	Ferrule	Diameter	1.4	3.55
		Length	1.5	3.81
	Length of spike		3.125	7.92
Packing-box	Length		121.0	307.83
	Width		6.0	15.24
	Depth		6.5	16.51
			Pounds.	Kilograms.
Weight of English rocket-stand			30.0	13.6
Weight of English rocket-stand and packing-box			73.5	33.34

VIII.—ROCKET-FUSE.

The life-saving rocket fuse is a frustum of a cone in shape, made of paper and covered with kamptulicon. It is 1″.5 long and fits the vent in the base of the rocket, which is 1″.0 in diameter. The fuse is covered with a paper cap tied on with twine.

The bore of the fuse is filled with about an inch of ordinary fuse composition and burns about five seconds. The paper cap may or may not be removed before firing. The fuse is ignited by means of a port-fire.

IX.—PORT-FIRE.

The Boxer port fire for life-saving apparatus has a total length of 9″.3, and is cylindrical in form. The exterior diameter of the case is 0″.7. One end is closed with a tin cap and a piece of kamptulicon; this cap is 0″.5 long and 0″.8 in exterior diameter.

On one side the tin band of the cap is perforated to admit a detonating primer that enters a small space under the kamptulicon, and fires the priming of mealed powder. The exterior surface of the port-fire is painted flesh color. A circular black spot on the cap indicates the position of the hole for the detonating primer. The time of burning of this port-fire is six minutes.

1.—PACKING PORT-FIRES.

The port-fires are packed in tin cylinders, containing 25 port-fires each. These cylinders are 9″.6 in length and 4″.5 in diameter. A paper cylinder lines the inside of the tin one.

A paper cap pasted on the upper end of the port-fire cylinder bears the following printed upon it: "25 Port-fires, Life-Saving Apparatus, Mark I. Not to be opened until required for use or special inspection." This is followed by the date, government mark, and place of manufacture, thus:

"8 | 9 | 77"
"R ↑ L"

2.—A label pasted upon the cylindrical surface has the following legend printed upon it:

"*To open the cylinder.*—Take hold of the overlapping unsoldered end of the tin band, and tear off the band by a sharp pull or jerk. The pull must be from left to right, with the bottom of the cylinder against the body."

X.—ROCKET-LINE.

The English rocket line is a loosely twisted Italian hemp line. No lines were sent with the apparatus received at Sandy Hook.

XI.—FAKING-BOX.

The faking-box used in the English service does not differ materially from our own. In fact our service-box was modeled after the English box. None of the latter accompanied the apparatus.

XII.—WRECK-LIGHT.

1.—DESCRIPTION.

This light is used for illuminating the beach at night in the vicinity of a wreck. It is hung upon a tripod and burns from 24 to 30 minutes. The tripod is a simple affair, consisting of three wooden legs, 6′ 4″ in length, weighing 12.5 pounds. The legs are connected at the top by an iron wire with a hook attached for suspending the light by a wire loop at its upper extremity. Three iron rods hooked to two of the legs form an inclined rest for the light, so that it may "hang in a sloping direction—not vertically downward."

The case is made of six cylindrical lengths of about 4″.5 each, fitted

end to end, and held by small tin bands half an inch in width. The joints are soldered. The case is filled with composition, and has the lower end primed with mealed powder and covered with kit plaster.

The method of hanging enables the light to clear itself of dross when burning. The heat of the burning composition successively melts the solder that holds the segments together, allowing the empty ones to fall to the ground, and prevents the partial obscuration of the light.

The following printed directions are pasted upon the exterior of each light:

This light must not be roughly handled or thrown about, as it is liable to be broken across at the junction of the segments. Care must be taken in removing the cap before lighting.

The case must be grasped firmly at the capped end whilst the cap, is torn off by means of the string loop. If there is any difficulty in removing the cap, it must be eased off around the edge by inserting the blade of a knife.

The lights are packed in rough lumber boxes containing three lights each.

The lights sent to Sandy Hook for trial are known as "Mark II," and were packed in July, 1877.

2.—WEIGHTS.

	Pounds.	Kilos.
Weight of wreck-light	11.5	5.18
Weight of box containing three (3) lights	61.0	27.67

Time of burning, 24 minutes and 10 seconds.

XIII.—ROCKET-BOXES.

These are oblong rectangular boxes, beveled at the upper end and covered with tarred canvas to render them water-proof The beveled top has a hinged lid fastened with a hasp, and has a projecting flap of tarred canvas hanging down over the edges to exclude the rain when carried in driving storms.

The capacity of each box is just sufficient to accommodate one rocket standing on end, without the stick. A set of cross belts or kind of harness enables the carrier to sling the box upon his back after the fashion of a knapsack. Four of these boxes accompany each set of rocket apparatus. The weight of the empty box with sling-belts is 9 pounds.

XIV.—METHOD OF USING.

With the apparatus on the ground where it is to be used, place the rocket-stand in position, giving the necessary elevation by means of the graduated arc on the side of the trough and the plummet.

Take a Boxer rocket, insert the stick through the clips and, drive in the clip-pin. Then wet about 12 feet of the end of the line and insert the end through the hole in the bottom of the rocket-stick, carry it along the stick to the hole near the upper end, draw it through and put on, first, a rubber washer, and then a brass one, and tie a knot in the end, drawing the whole down snugly upon the end of the stick. It is better to tie a knot in the line after passing it through the hole in the rear end of the stick, so that in case the line burns off between the rocket and lower end of the stick the knot will catch and the line still be carried out.

Remove the paper cap on the base of the rocket and insert a fuse. Place the rocket and stick in the trough of the stand, sliding them to the rear until the base of the rocket brings up against the front end of

the curved trough or pry-pole. Put the faking-box, slightly inclined to the front, in rear of the stand and a little to one side.

Insert a port-fire in the holder and ignite it with a detonating primer. Advance to the stand, insert the port-fire in the opening on the side opposite to that on which the faking-box and line are placed, light the rocket-fuse, and retire towards the rear.

XV.—ACTION.

As soon as the rocket composition is ignited and sufficient gas is evolved, the rocket starts, guided by the trough and the rocket-stick.

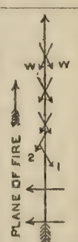
After traversing a part of its trajectory, the composition in the rear cylinder is consumed, the solid part between the cylinders burns through and sets fire to the composition in the forward cylinder, giving a new impetus to the rocket and prolonging the range.

NOTE.—The writer would here acknowledge his obligations to the "Treatise on Ammunition, 1874," by Maj. W. R. Barlow, R. A., for much information in regard to the English life-saving rockets and rocket stores.

XVI.—EXPERIMENTS WITH LIFE SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

1.—*Record of firings with Boxer life-saving rockets and apparatus* (*English*).

Date.	Number of fire.	Elevation.	Kind of rocket-stand.	Life-saving rocket. Caliber.	Life-saving rocket. Kind.	Life-saving rocket. Weight.	Life-saving rocket. Total weight of rocket and stick.	Primer.
1879.		°				*Pounds.*	*Pounds.*	
Oct. 18	1	35	Boxer, Mark IV ..	12-pounder....	Boxer, III ..	14.25	17.41	Fuse, Mark I.
18	2	35	....do	....do	....do	14.25	17.41	Do.
18	3	30	....do	....do	....do	14.25	17.41	Do.
18	4	30	....do	....do	....do	14.25	17.41	Do.
20	5	29	....do	....do	....do	14.25	17.41	Do.
21	6	30	....do	....do	....do	14.25	17.41	Do.

Date.	Number of fire.	Shot-line. Material.	Shot-line. Number of line.	Shot-line. Length.	Shot-line. Action.	With what fired.	Range.	Deviation of rocket right or left.	Drift of shot-line at 300-yard stake right or left.	Wind. Direction.	Wind. Velocity.
1879.				*Yds.*			*Yds.*	*Feet.*	*Feet.*		*Miles per hr.*
Oct. 18	1	Italian hemp....	6	600	Good, but burned off.	Port-fire, English.	......	......	......		15.9
18	2	Linen, W. P.....	6	600	Good........	...do	......	......	......		22.5
18	3	....do	6	600	Knotted and burned off.	...do	......	......	......		20.0
18	4	....do	6	600	Good, two knots.	...do	540	241 R.	121 R.		18.0
20	5	Linen, W. P.; new line.	8	600	Good, one knot.	...do	$511\frac{2}{3}$	172 L.	126 L.		16.0
21	6	Hemp line, Russian rocket.	*8	†600	Bad	...do	125	6 R.	......		16.0

NOTE.—The rocket-lines used were the Silver Lake Company's braided lines, except that used for the last round. This was a Russian hemp line, loosely "laid up"; weight, 62 pounds.

R. = Right; L. = Left; W. P. = Water-proof.

* Estimated.

2.—Synoptical transcript of notes from the firing record.

Boxer life-saving rockets and apparatus.

Date.	No. of round.	
1879.		
Oct. 18	1	End of line attached to rocket was left dry; line burned off.
18	2	Line dry; burned off between the knots; the second knot drew through the hole in the lower end of the rocket stick when the strain came upon the line.
18	3	End of line wet; still it was burned off by the escaping flame from the rocket.
18	4	Good shot; one rubber washer placed below lower knot to prevent cutting the line should the knot be drawn through the hole in the lower end of the rocket stick; when recovered the staff was found to be broken and badly charred; the velocity of the wind at ordnance office, near the firing point, was, at the beginning of the day's experiments, 16 miles per hour; at the close, 14.6 miles per hour; the direction was very changeable; at the last shot, the wind along the first half of the trajectory was from the left and front, while it was blowing from the right and front in the farther half at the same time, as shown by the range flags that marked the line of fire.
20	5	No. 8 linen water-proof line used (new); fired from the original coil; rocket carried out all the line except six coils; wet the line below the end of the rocket-stick; the line fouled once from the coils catching on each other; one knot formed; the original coil was placed 6 feet to the right of the stand (windward), inclined to the front and backed up by sand; the knot was 200 yards from the firing point; line drifted badly after passing the 200-yard stake, and followed the drift of the rocket closely; rocket-stick charred by flame; every coil drawn out put one twist in line.
20	6	Russian rocket-line, weight, 62 pounds; line twisted, soft laid in original coil; many of the coils were loose and were expected to kink and *did* kink badly; the whirl of the line caught the coil and carried it bodily 100 yards down the range; the second knot was drawn down into the lower end of the stick, splitting it nearly to the ferrule; the rubber washer placed between the second knot and the lower end of the staff probably saved the line from being cut; the short range is accounted for by the resistance due to carrying the whole coil.

PART V.

Hooper's life-saving rocket apparatus.

I.—Hooper's life-saving rocket.

(Plate XI.)

1.—Description.

This rocket is a modification of the Hale rocket. The body of the rocket is cylindrical in form, made of sheet metal 0″.165 thick. The point of the rocket or head is ogival in form, made of wood, and has a cylindrical tenon 1″.1 in length, which is inserted into the front end of the body. The head is held in position by several screws passing through the rocket-case into the tenon. The rear end of the case is closed by a metallic base carrying a double swivel and perforated with five vents or gas escapes, each one half an inch in diameter. On one side of these vents are fluted projections extending 2″.3 towards the rear, so curved as to leave the opposite sides open for the unimpeded escape of the gases evolved by combustion. The object of this arrangement is to produce a motion of rotation about the longer axis of the rocket, and thus secure greater steadiness of flight. This cast-iron base is held in position by pins passing through the case.

To the swivel is attached a chain a little over 3 feet long, to which the line is made fast. The rocket is fired by breaking the paper covering of one or more of the vents, and inserting a piece of slow match and igniting the outer end.

2.—*Principal dimensions and weights.*

			Inches.	Centimeters.
Length of body			14.5	36.82
Diameter of body	Exterior		3.75	9.40
	Interior		3.42	8.64
Head	Total length		3.6	9.14
	Length of ogival part		2.5	6.35
	Diameter		3.75	9.40
	Tenon:	Length	1.1	2.79
		Diameter	3.42	8.64
Length of base outside of case			2.7	6.86
Total length of rocket			19.7	50.03
Length filled with composition			12.0	30.48
Diameter of vents			0.5	1.27
Number of vents			Five.	
Length of chain and swivel			38″.5	96.65
			Pounds.	Kilos.
Average weight of rocket and chain			19.25	8.73

For further details in regard to construction, action, and method of using, see Mr. Hooper's description appended below. In that description is included the rocket-stand proposed by Mr. Hooper.

No rocket-stand was furnished with these rockets, consequently the weight of that portion of the apparatus is unknown.

In the experiment with the Hooper rockets made by the writer, the German rocket-stand was used throughout the trial.

II.—Directions for the use of J. Singleton Hooper's life-saving rocket and stand.

1. The elevation required for the stand to be ascertained by means of a small quadrant; 25° will carry the line 300 yards with ease.

2. It is suggested, in order to save time, that every rocket-line should be spliced to a spring swivel that it might *at once* be attached to the end of the rocket-chain.

3. *In all cases three fathoms of the rocket-line to be wetted before being attached to the chain.*

4. Place the rocket in the trough or stand with its shoulder against the small iron projection at its base, and the chain hanging down through the slot.

5. To fire the rocket: With a pointed stick break the oil paper covering each of the flange holes, insert into one of them a slow match, light and retire to an angle of 45° to the rear of the stand.

J. S. HOOPER, *R. N.*

(Copy of printed record.)

III.—Improvement in rockets.

Specification forming part of letters patent No. 196019, *dated October* 19, 1877; *application filed May* 22, 1877.

(Plate XII.)

To all whom it may concern:

Be it known that I, James Humphrey Singleton Hooper, R. N., of Sunny Croft, Croxted Road, Dulwich, in the county of Surrey, England, have invented new and useful Improvements in Rockets for saving life and other useful purposes, and in the apparatus used in connection therewith, which improvements are fully set forth in the following specification, reference being had to the accompanying drawings.

This invention has reference to those rockets known as the "Hale

rocket," and consists of improvements in the means and apparatus for adapting such rockets to life saving and other useful purposes.

The object of these improvements is to more readily carry out a line to a shipwrecked or stranded vessel with certainty, and at any angle, according to the distance or height at which it is desired to throw the rocket, and may be used as a means of communication, and for other useful purposes.

To carry out my improvements I insert through the center of the flange or tail-piece of the Hale rocket a small iron, steel, or other metal spindle, with a head to it, the head being for the purpose of resting on a circular bearing, for the purpose of retaining the spindle in position, made in the interior of the flange or tail-piece. The action of the spindle working in this bearing is what I call my "first swivel." To the end of this pin or small spindle, which projects beyond the end of the flange of tail-piece, I attach a swivel-bow or other mechanical equivalent being capable of rotation, and this I call the "second swivel," thus making a complete double swivel, to which is attached a short length of chain. The swivel and chain being both clear of the rear fire I can, without burning, attach any description of line.

And in order that my said invention may be properly understood and carried into effect, I will now proceed to describe the same, reference being had to the annexed drawings (Plate XII) and to the letters and figures marked thereon.

Figure 1 represents an external view of rocket known as a "Hale rocket," and shows my improvements attached thereto. Fig. 2 represents a longitudinal section of the same, and shows more fully the internal mechanism and my double swivel. Fig. 3 represents a transverse section of the rear end of the rocket, taken on the line A B. Fig. 4 represents a transverse section through the tail-piece or rotator on the line C D.

To carry out these improvements I insert (for about half its length) through the center or longitudinal axis of the tail-piece or rotator *j* a spindle or bolt, *n*, with a collar or head, *o*, at that end of it which is within the tail-piece or rotator *j*. This tail-piece or rotator is recessed to receive the collar or head of the spindle or bolt *n*, so that the under side of the collar, or head *o*, bears against the shoulder *p*, formed by the recess in the tail-piece or rotator *j*, by which arrangement, though the spindle or bolt *n* is retained in its position in rotator *j*, and securely held within the same by the collar or head *o*, so that it cannot be withdrawn, yet it is perfectly free to turn or rotate on its own axis (after the well known manner of a journal in its bearing), and this I call, from its having such a rotary action about its axis, my "first swivel." Further, to that end of this same spindle or bolt *n* which projects beyond the tail-piece or rotator *j*, I attach an ordinary swivel-bow or shackle, *g*, free to turn or rotate on the aforesaid bolt *n* but securely retained to the same by the nut *r* on the screwed end of the spindle or bolt *n*. This nut is also further secured from unscrewing by the cross-pin *s* passing through the same.

The second swivel (bow) works on the steel bolt in a recess, *g′*, cut in the rear of tail-piece. The swivel is, therefore, safely protected from the back fire injuring its working faces. This last-described swivel-bow *g* (or shackle free to turn on its axis) I call my "second swivel," and to it is attached a small length of chain, *t*, to the end of which is fastened one end of the rope or cord to be carried out.

It will be seen by this combination of parts which I have adopted, the greatest liberty is given to the rocket to rotate on its axis free from any impeding action to such rotation by the rope attached as is experi-

enced in the stick-rocket at present in use, and to supersede which is one of the real objects of this invention; for in my method the whole of the parts, both of the rocket proper and also the double swivel, as well as the chain itself, is equally balanced about the axis of rotation, and therefore these parts do not impede the equal action of rotation, nor tend to cause the rocket to deviate from its true path of flight.

By the double swivel-action of my invention I effectually guard against the danger of one swivel not acting, for should one of them cease to act there is still the other swivel, which is perfectly capable of performing all that is required, so that the first or the second swivel may severally perform, apart from any assistance from the other, its proper, office of permitting the rocket to rotate without itself or chain attachment and rope rotating; or they (the swivels) both may share more or less equally between them their functions, thus insuring in my case a perfect swivel-action between the rocket proper and the rope.

The cavity at the back of the head *o* of the bolt *n* is plugged with a plug, *u*, which protects the bolt from damage. This plug *u* is made parallel, and the head u^2 is coned, thereby diverting the fire into the flange-holes more readily, and the shoulder under the head, in conjunction with the tight fit, when resting on a similar circular bearing to that on which the bolt-head *n* rests, effectually secures the head of the bolt *n* from damage while the combustion of the composition a^1 is going on in the case *a* during the flight of the rocket, the space between the two bearings being filled with tallow.

Fig. 5 represents a side elevation of the stand from which the rocket is fired, and Fig. 6 the back end view of the same to a larger scale.

This stand consist of two pieces, *v* and *v′*, of wood, iron, or other suitable material (when of the first-mentioned substance they are covered with thin sheet-iron), fastened together parallel to each other, with their upper surfaces inclined to one another about one hundred and sixty degrees, or thereabout. These pieces *v v′* are connected, at three or more places, by semicircular bands or hoops *w*, of iron or other suitable material, which bridge from the outside of one piece, *v*, to the outside of the other piece, *v′*. The near sides of these pieces, *v* and *v′*, are placed at such a distance apart that the chain *t* and rope *x*, connected to the tail of the rocket, may be able to freely pass between them without any danger of its being caught by the sides.

The stand is supported at the front end by two double-jointed legs, *y*, with spikes at their extremities or bases, and is supported at the rear end by two shorter legs, *z*, of iron or other material. There is a small projection, *z′*, on one of the pieces *v* and *v′*, for the rear end of the rocket to rest against when it is fired, which is performed by a slow match or fuse.

Another advantage of my invention is, that the improvements adopted are very light and portable, and require but a simple stand (already described) to fire from, thus doing away with the complicated machinery at present in use with the stick life-saving "boxer" or other rocket.

Having thus described the value and object of my said invention, I claim—

1. The combination, with the Hale rocket, of a swivel, to which the line is attached, secured to the tail-piece of said rocket, whereby the line is carried without being twisted by the rotation of the rocket, substantially as described.

2. The combination, with the tail-piece *j*, of the bolt *n*, rotating freely in said tail-piece, and the swivel *g*, secured to the end of the said bolt, constructed and arranged substantially as described and shown.

3. The combination, with the tail-piece *j*, of the plug *u*, having a conical head, u^2, for protecting the swivel-bolt and diverting the fire into the flange-holes, constructed and arranged substantially as described and shown.

JAMES HUMPHREY SINGLETON HOOPER.

Witnesses:

GEO. DOWNING.

GEO. FORBES.

IV.—EXPERIMENTS WITH HOOPER'S LIFE-SAVING ROCKETS.

EXPERIMENTS WITH LIFE-SAVING APPARATUS AT SANDY HOOK, NEW JERSEY.

1.—*Record of firings with the Hooper life-saving rocket.*

Date.	Number of fire.	Elevation, degrees.	Kind of rocket-stand.	Rocket, kind of.	Primer.	With what fired.	Where fired.	Line attached or not.	Rocket exploded in air or not.	Wind.	
										Direction.	Velocity.
1879. Oct. 20	1	° 26.5	German.	Hooper life-saving.	Slow match.	German pillenlicht.	On beach..	Yes.	No.		
20	2	26.5	...do	....do	..do....	....do	....do	Yes.	No.		
20	3	26.5	...do	....do	..do....	....do	....do	Yes.	Yes.		
21	4	32	...do	....do	..do....	....do	....do	Yes.	Yes.		
21	5	32	...do	....do	Train quick match.	....do	....do	Yes.	Yes.		
21	6	32	...do	....do	..do....	....do	....do	Yes.	Yes.		
22	7	30	...do	....do	..do....	....do	Out to sea..	No.	Yes.		
22	8	30	...do	....do	..do....	....do	....do	No.	Yes.		
22	9	30	...do	....do	..do....	Port-fire, U. S.	On beach..	No.	Yes.		
22	10	30	...do	....do	..do....	....do	....do	No.	Yes.		
22	11	30	...do	....do	..do....	....do	....do	No.	Yes.		
22	12	30	...do	....do	..do....	....do	....do	No.	Yes.		
Nov. 14	13	30	...do	....do	..do....	....do	Out to sea..	No.	Yes.		
14	14	30	...do	....do	..do....	....do	....do	No.	No.		
14	15	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	16	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	17	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	18	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	19	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	20	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	21	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	22	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	23	30	...do	....do	..do....	....do	....do	No.	Yes.		
14	24	30	...do	....do	..do....	....do	....do	No.	Yes.		

PLANE OF FIRE

2.—SYNOPTICAL TRANSCRIPT OF NOTES FROM THE FIRING RECORD.

Hooper's life-saving rocket, using the German rocket-stand.

Date.	No. of round.	
1879.		
Oct. 20	1	Italian hemp line, Silver Lake, No. 7. Rocket carried out about 300 yards of line, when it burned off the line near the chain. Rocket-chain too short—length 37 inches. Faking-box and line placed at the right of the rocket-stand, and a little in rear of it. The position of the box and line appeared to change the direction of the rocket about 20° to the left of the line of fire. The line ran out beautifully until burned off, 300 yards away. No stand furnished with the Hooper rockets; had to use the German stand.
20	2	Same line, in coils, hauled in hand-over-hand. Line broke; probably fouled in the coils and cut by drawing through. Action of rocket good. Range of rocket over 700 yards at least.
20	3	No. 7 line. Line cut by sharp corners on legs of stand. Rocket carried away a piece of the line. Range unknown. Rocket burst in the air beyond the 400-yard stake.
21	4	No. 7 hemp line. Wet 10 feet of the line. Range 175 yards; deviation of rocket to left of line of fire 42 feet. Rocket exploded, blew out front end of the rocket, and dropped to the ground as soon as the explosion took place.
21	5	Same line hauled in hand-over-hand. Rocket blew up in the trough of the rocket-stand. Head blew out and rocket fell backward out of the stand.
21	6	Same line. Rocket exploded in the air 150 yards from firing point; carried off piece of line; coils caught. Line cut by drawing through the coils. Range 280 yards. The line lay in loose coils as hauled in.
22	7	No line; rocket exploded in the air.
22	8	No line used from this time until end of experiments with this rocket. Rocket burst in the air 1¼ seconds from instant of leaving trough.
22	9	Exploded in 1¼ seconds after leaving trough.
22	10	Exploded in the trough ¼ second after composition was lighted. The breech was blown out and the rocket-case ruptured from end to end. Gas and sand blown in face of firer, who had a narrow escape from being seriously injured.
22	11	Long trains of quick match used from this time out to enable firer to reach a safe distance. Rocket exploded about 300 yards out. Flight of rocket regular until it burst. Time lost.
22	12	Rocket exploded 20 yards in front of stand.
Nov. 14	13	Rocket exploded in the air.
14	14	Fired out to sea; good range. Rocket did not explode.
14	15	Burst immediately in front of stand.
14	16	Rocket burst 200 yards out.
14	17	Burst short distance in front of stand.
14	18	Burst 20 yards in front of stand.
14	19	Rocket burst 30 yards in front of stand.
14	20	Rocket exploded in front of stand.
14	21	Same remark.
14	22	Rocket exploded 50 yards in front.
14	23	Rocket exploded in the air.
14	24	Rocket exploded in the air.

PART VI.

Conclusion.

I.—RECAPITULATION OF WEIGHTS.

1.—*Russian life-saving rocket apparatus.*

	Pounds.	Kilos.
Weight of rocket and stick	25.5	11.56
Weight of rocket-stand	39.0	17.69
Weight of rocket-chain	4.625	2.19
Weight of portfire handle	.5625	0.25
Total weight	69.6875	31.69

2.—5^{cm} *German life-saving rocket apparatus.*

	Pounds.	Kilos.
Weight 5 ^{cm} rocket	10.	4.53
Weight of rocket stick and chain	5.5	2.49
Weight of rocket-stand	35.	15.98
Weight of firing-staff	2.	0.91
Total weight	52.5	23.91

3.—8cm German life-saving rocket apparatus.

	Pounds.	Kilos.
Weight of 8cm rocket	35.0	15.98
Weight of rocket stick and chain	7.25	3.29
Weight of rocket-stand	35.	15.98
Weight of firing-staff	2.	0.91
Total weight	79.25	36.16

4.—8cm German anchor-rocket apparatus.

	Pounds.	Kilos.
Weight of 8cm anchor rocket	37.375	16.95
Weight of rocket stick and chain	9.	4.08
Weight of rocket-stand	35.	15.98
Weight of firing-staff	2.	0.91
Total weight	83.375	37.92

5.—English life-saving rocket apparatus.

	Pounds.	Kilos.
Weight of rocket	14.25	6.46
Weight of rocket-stick	3.16	1.43
Weight of rocket-stand	30.	13.60
Weight of rocket carrying-box	9.	4.08
Total weight	56.41	25.57

6.—Hooper life-saving rocket system.

	Pounds.	Kilos.
Weight of rocket and chain	19.25	8.73

The other weights in this system are unknown.

A glance at the above figures will show that the great advantage of rocket systems lies in their small weight and extreme portability.

The faking boxes and lines have been omitted in the above comparison, as their weights would differ but little from each other in the several services, provided the same size faking-line was used.

II.—Russian rocket apparatus.

The Russian system is the most unwieldy rocket apparatus that was tried. The stand is inconvenient to handle. The tube from its form is liable to be collapsed and disabled. The manner of attaching the chain to the line is objectionable, as it increases the weight of line (already a heavy one, 62 pounds) and faking-box. The chains must be spliced to the lines in advance and kept ready for use. Again, the sudden jerk upon the chain as the hook on the rocket-stick picks it up is very apt to break the chain, made, as it necessarily is, of a rigid material. The rockets themselves were very unsatisfactory, nearly all of them exploding. In general the case obtained relief from the pressure of the imprisoned gas by blowing out the base. The great number of vents surrounding the screw-hole in the base weakens this part by diminishing the thickness of the walls between the holes. The rupture usually took place through these vent partitions.

The firing record shows that this system is unreliable.

III.—The German rocket apparatus.

None of these rockets failed and the ranges obtained are good. The drift of the rocket from the plane of fire, due to the influence of the wind, is very marked. This is to be expected in any class of projectiles that are growing lighter all the time while describing their trajectories.

The effect of the wind will generally be more noticeable in the falling branch of the trajectory when the composition is nearly or quite burned out and the rocket is rapidly losing its velocity.

The whole of the German apparatus bears evidences of that careful workmanship and painstaking in details which characterize their fabrications. Every part is substantial and is made of the best material.

The German rocket-stand gave universal satisfaction, and was the favorite among the surfmen. These rockets are very expensive, and would make ordinary practice drills very costly affairs. The cost of the rockets is as follows:

5^{cm} life-saving rocket	$3.60
8^{cm} life-saving rocket	5.80
8^{cm} anchor rocket	24.24

It will be seen from the above prices what would be the cost of a single shot with either of the rockets, forming quite a contrast with the ordinary practice shots in the United States life-saving service, which cost less than seven (7) cents each.

In the latter service old lines may be used for practice with light charges. In the case of rockets, where the charges cannot be reduced at will, good lines must be used for the exercises, as old or worn lines would be continually breaking.

It has been recommended that the German rockets be still further tested, which will be done at an early date. The German rockets being so strong and well made have inspired greater confidence in the surfmen of the upper Jersey coast than any of the other rockets. And even with these they prefer to insure safety by retiring to a distance after igniting the fuse.

IV.—English rocket apparatus.

The Boxer rocket is so well known as to require no special mention of its peculiarities. Like all rockets it is somewhat erratic in its flight, and the more so probably from the position of its stick upon the side. It has grave disadvantages in this, that should it, by the wind or from any other cause, veer slightly from its original direction when the second rocket in front ignites, it gives an impulse entirely in the wrong direction. Plate XIII shows the effect on two Boxer rockets arising from winds blowing from right to left. In the first case the rocket "ran up into the eye of the wind," in the second the rocket and line floated off bodily to the left with the wind. This apparatus appears to be too complicated. Too many detonating primers, fuses, portfires, holders, boxes, tin cylinders, washers, and clip-pins to suit life-saving crews along our coast. As one surfman aptly remarked while working with it, "there is too much *tender* work about this thing." There is yet trouble in fixing the sticks to the rockets, though the clip-pin holes have been placed in front of the clip.

English officers have found fault with the keeping qualities of these rockets. The effect of storage on those at Sandy Hook will be rendered apparent at the next inspection and trial.

V.—Hooper life-saving rockets.

These rockets failed very badly. Nearly all of them exploded, some of them before leaving the trough of the rocket-stand. Several of these were very dangerous. Captain Patterson was slightly injured by the

explosion of one of these rockets. After that the men all retired to bomb-proofs, and the rockets were fired by trains of quick match.

The heads blew out frequently, but occasionally one was ruptured longitudinally. The chain is too short, allowing the line to be burned off.

These rockets appear to be very carelessly manufactured.

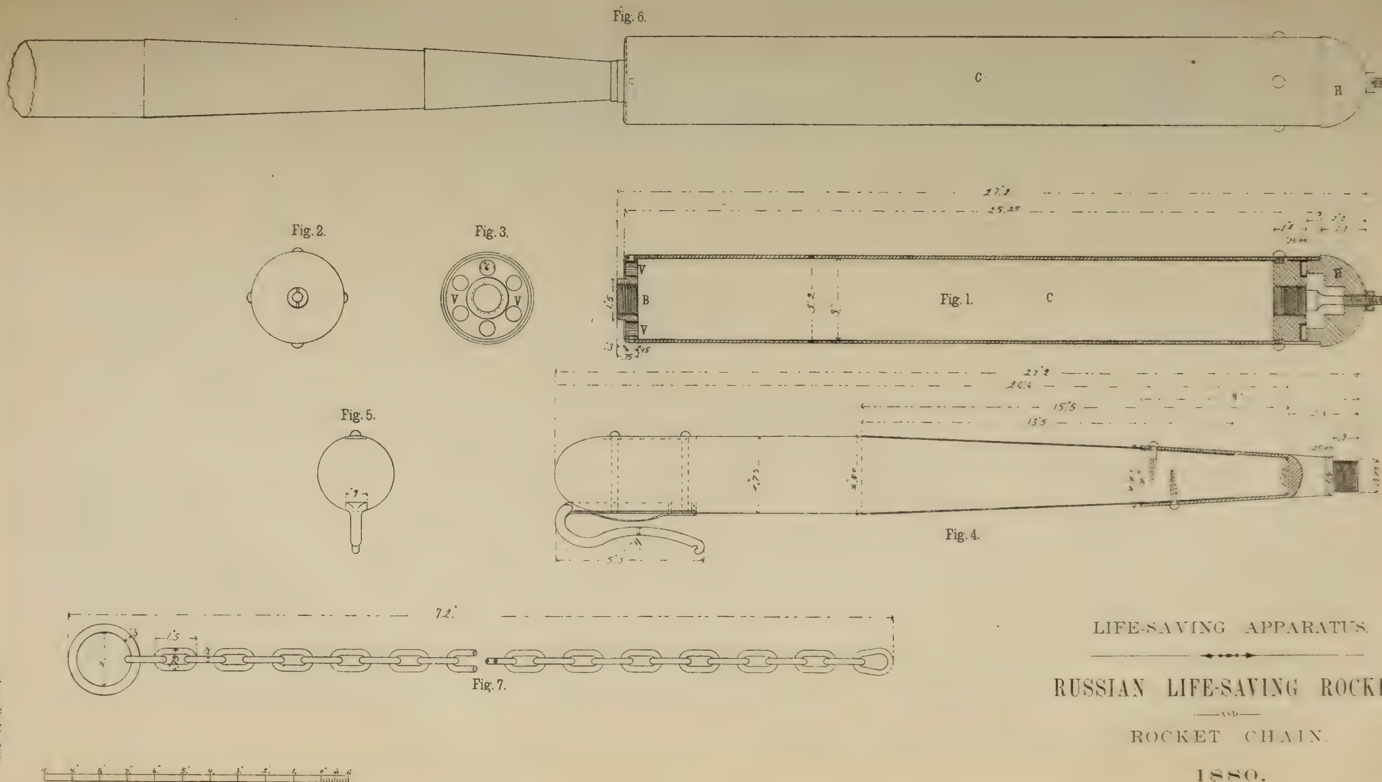
VI.—General remarks.

These trials have shown that life-saving rockets should not be handled by persons unacquainted with the necessity for avoiding jars and shocks. If, in transportation, the packing-boxes are roughly treated, the shocks communicated to the rockets cause more or less vibration, and gradually loosen the case from the composition. This effect is hastened by changes of temperature expanding and contracting the metal cases.

As soon as the composition gets a little loose in the case, cracks are liable to be found extending from the *bore* to the case. These openings allow the fire to penetrate between the rocket-case and composition enveloping the latter in flames, and setting free an amount of gas which the case is unable to sustain. With this violent pressure it is not strange that many of the rockets should burst explosively.

The liability to injury from corrosion where exposed to the moist sea air is always present, no matter what rocket system be used.

In short it may be said that with rockets one never knows what may happen, nor where they will go when fired.



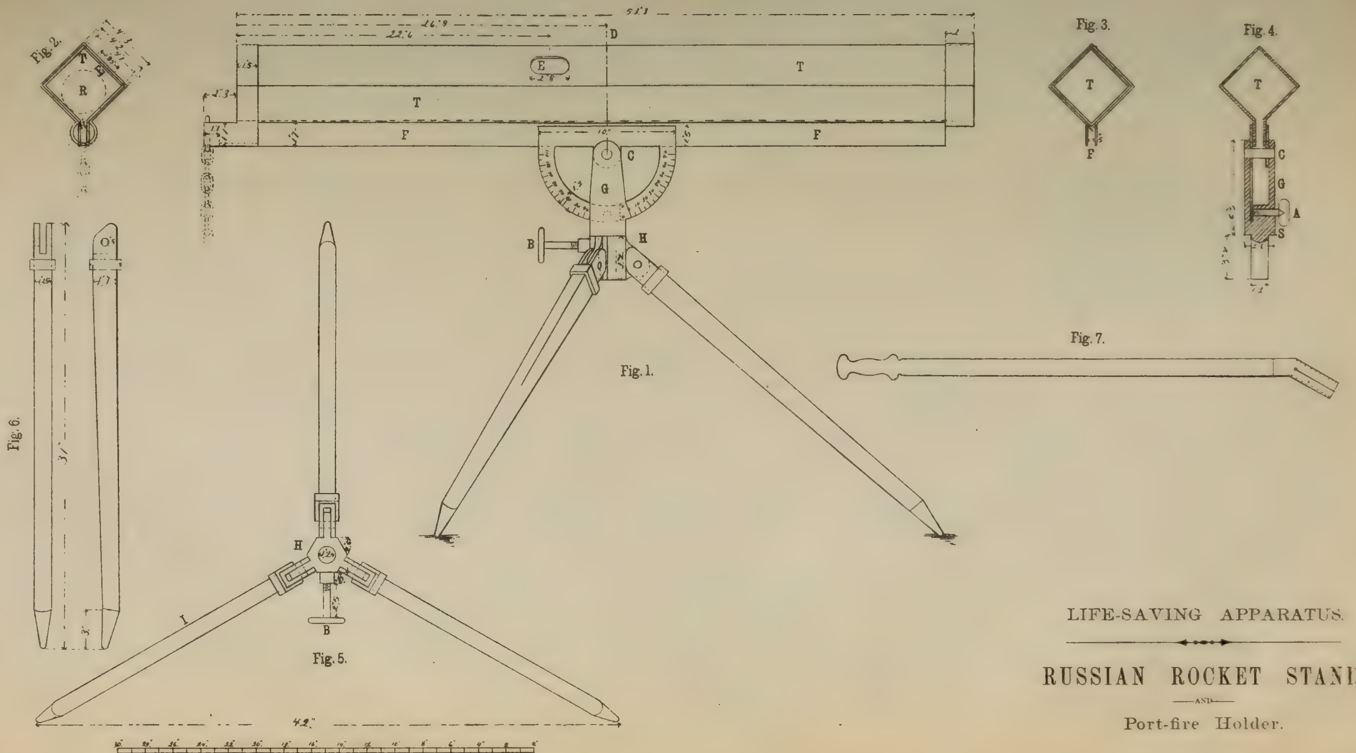
LIFE-SAVING APPARATUS.

RUSSIAN LIFE-SAVING ROCKET.

AND

ROCKET CHAIN.

1880.



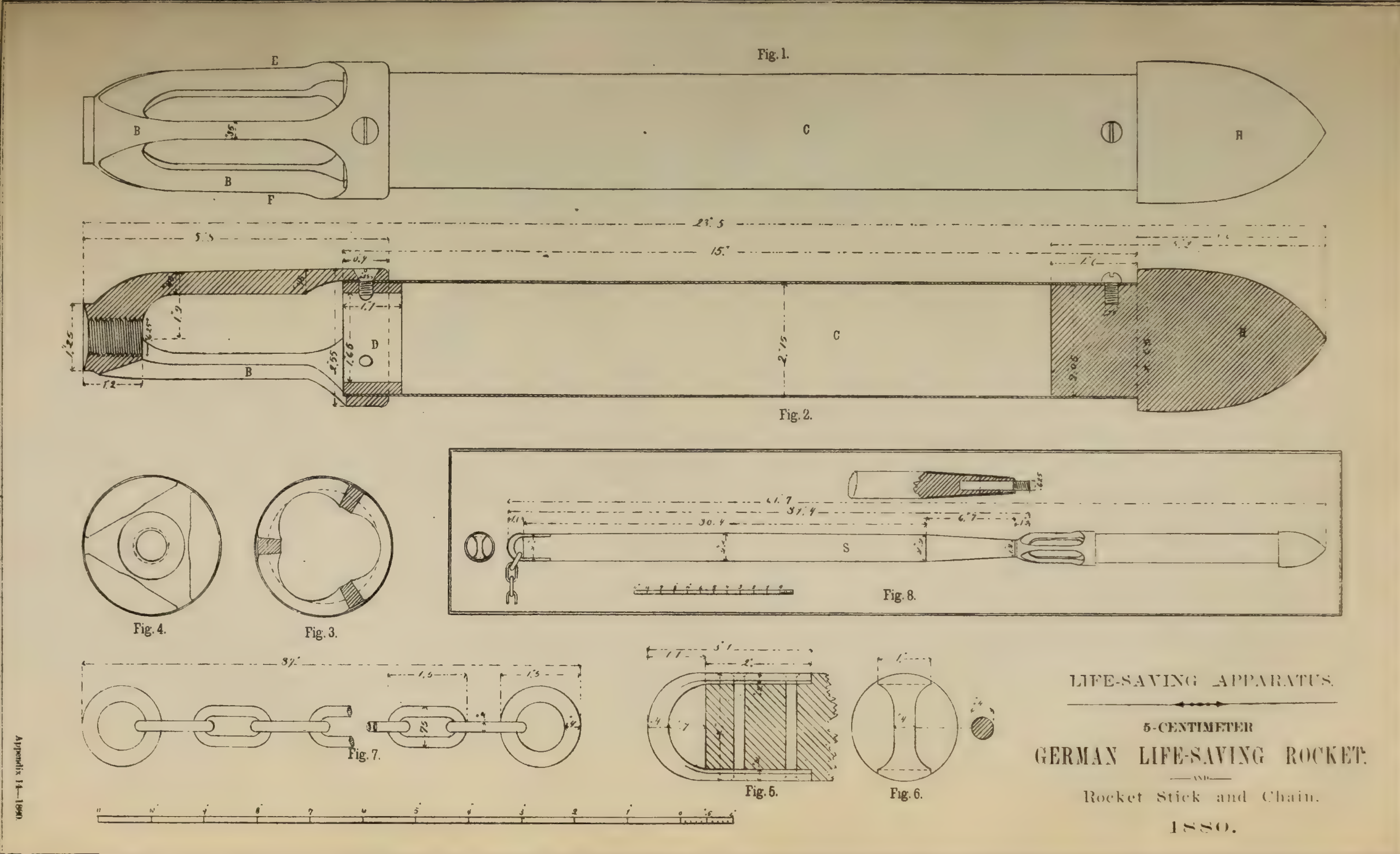
LIFE-SAVING APPARATUS.

RUSSIAN ROCKET STAND,

AND

Port-fire Holder.

1880.



LIFE-SAVING APPARATUS.

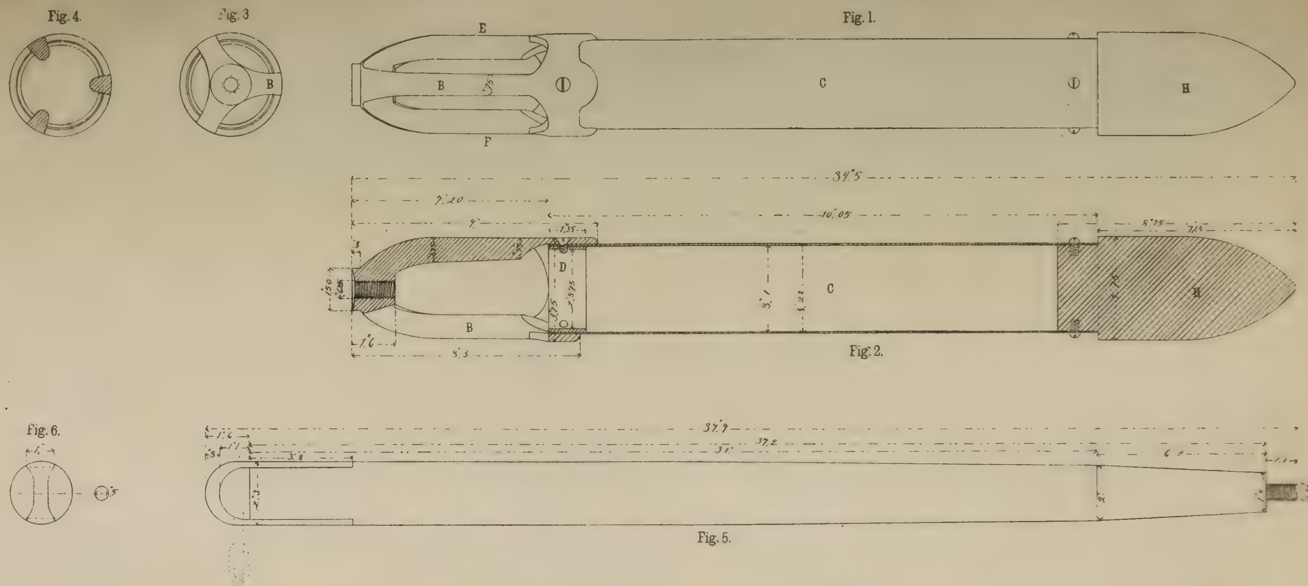
5-CENTIMETER

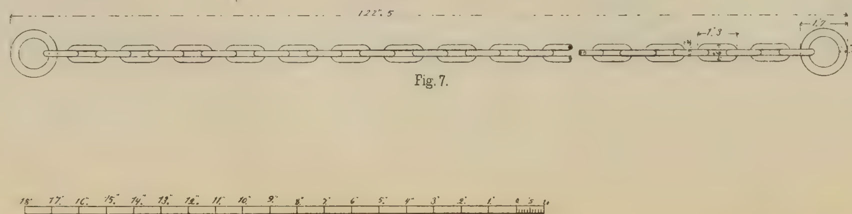
GERMAN LIFE-SAVING ROCKET.

AND

Rocket Stick and Chain.

1880.





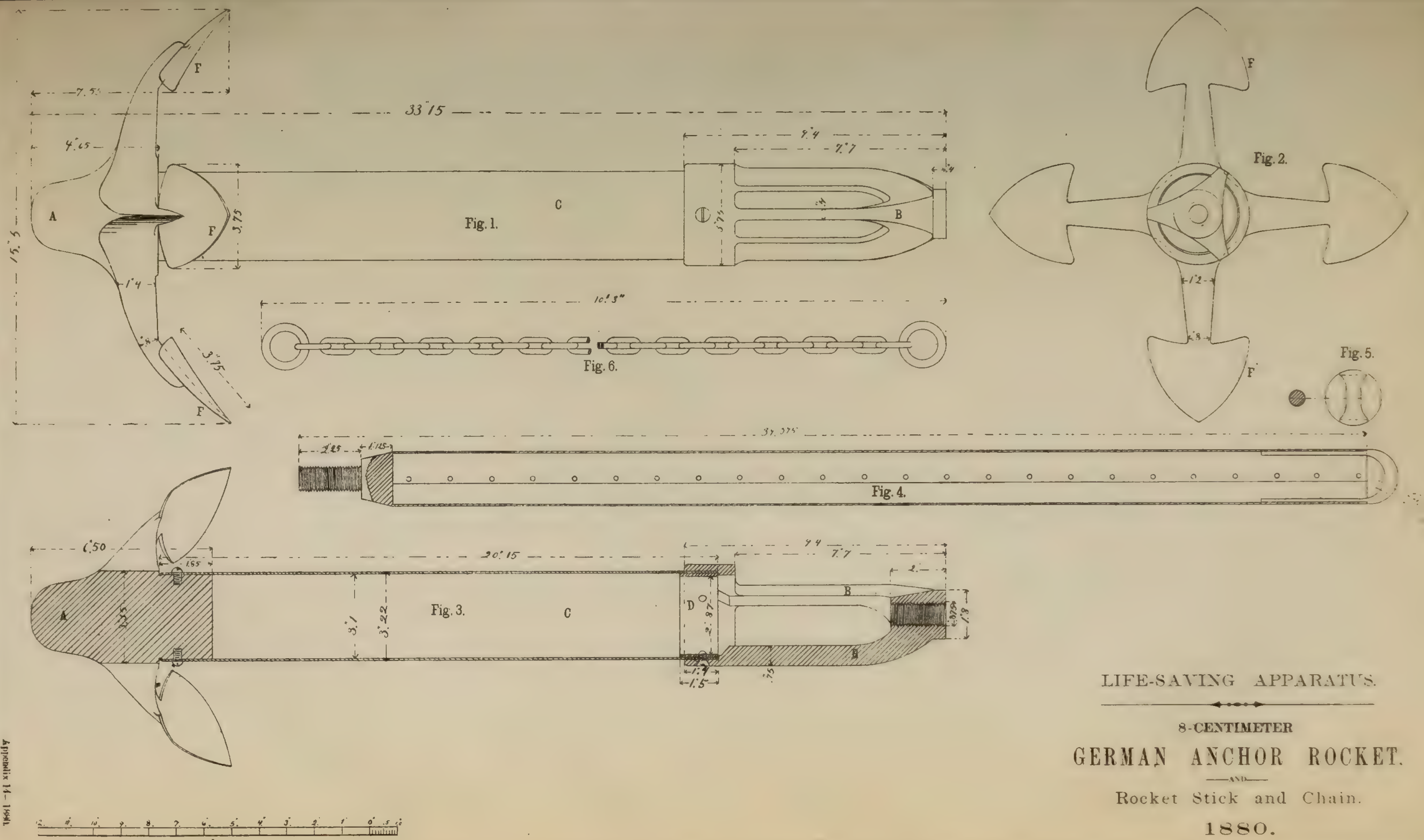
LIFE-SAVING APPARATUS.

8-CENTIMETER

GERMAN LIFE-SAVING ROCKET.

Rocket Stick and Chain.

1880.



LIFE-SAVING APPARATUS.

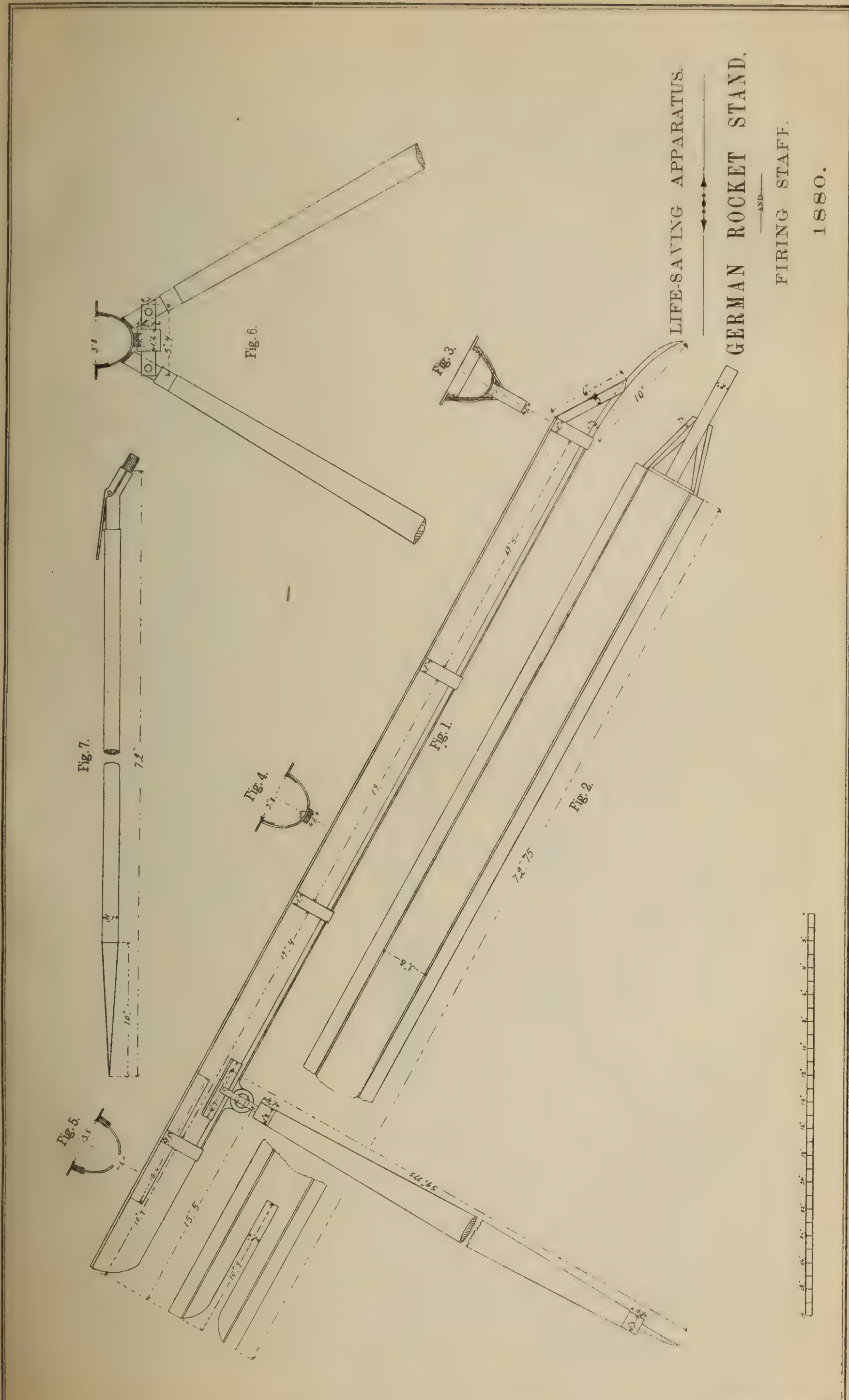
8-CENTIMETER

GERMAN ANCHOR ROCKET.

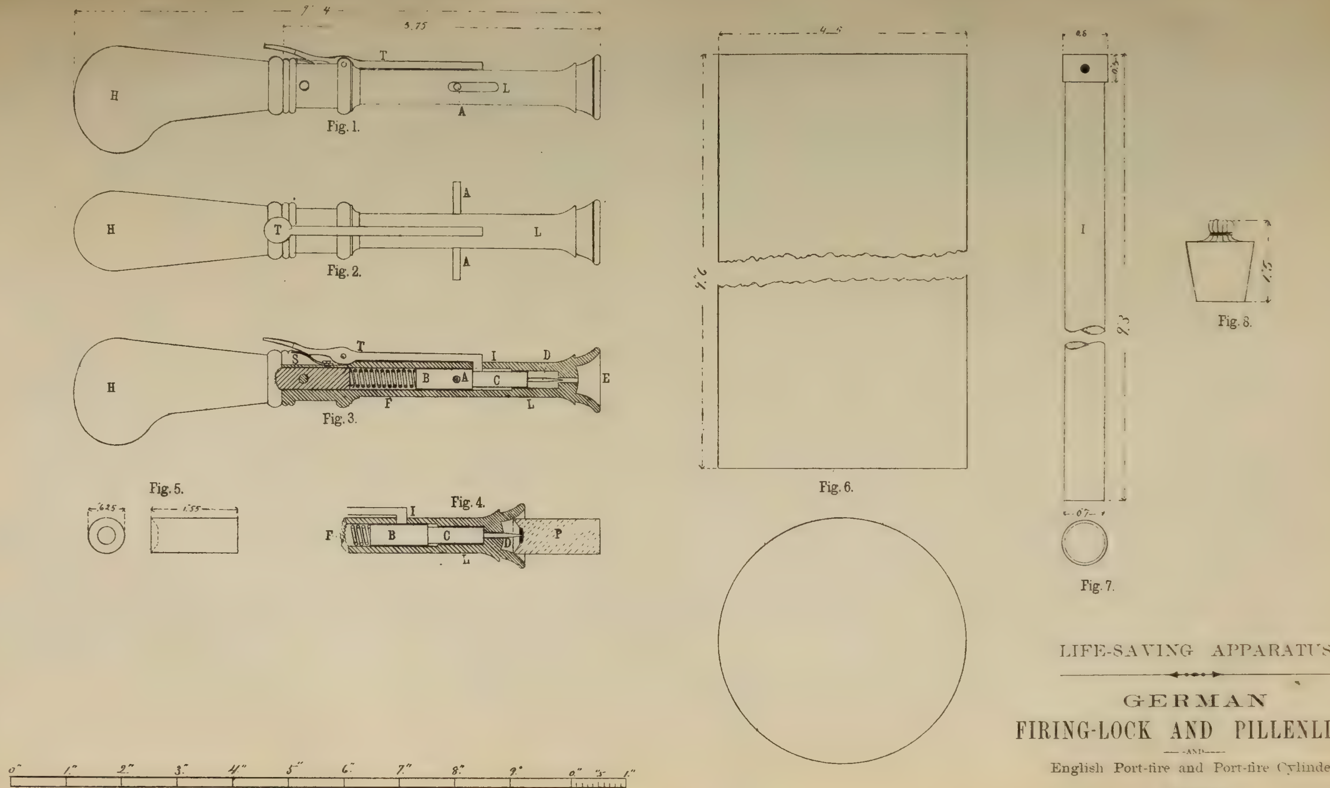
AND

Rocket Stick and Chain.

1880.



Appendix 14 - 1880.



LIFE-SAVING APPARATUS.

GERMAN

FIRING-LOCK AND PILLENLICHT,

—AND—

English Port-fire and Port-fire Cylinder.

1880.

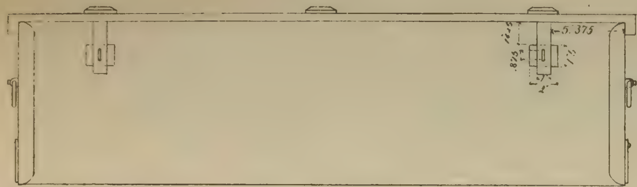


Fig. 1.

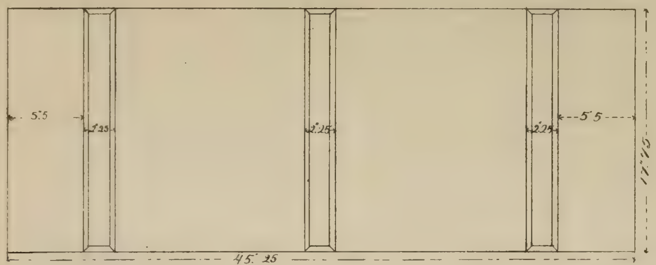


Fig. 2.

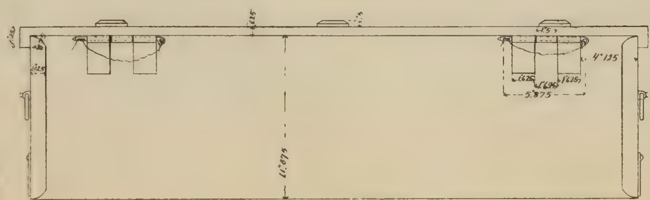


Fig. 3.

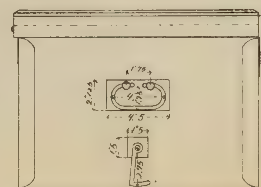


Fig. 4.

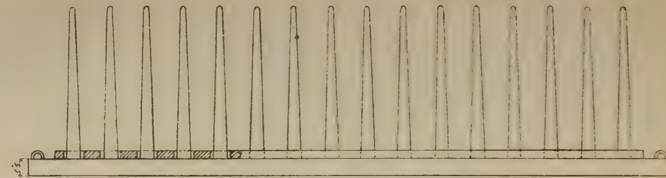


Fig. 5.

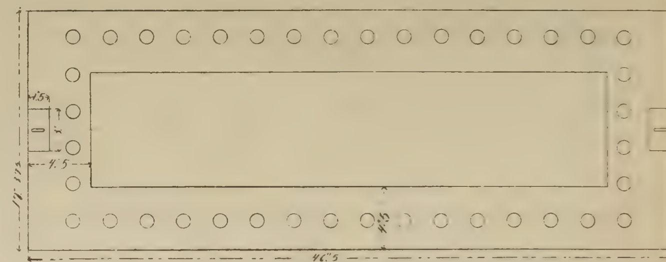


Fig. 6.

LIFE-SAVING APPARATUS.

GERMAN FAKING BOX.

SHOWING

Frame and Faking Pins.

1880.

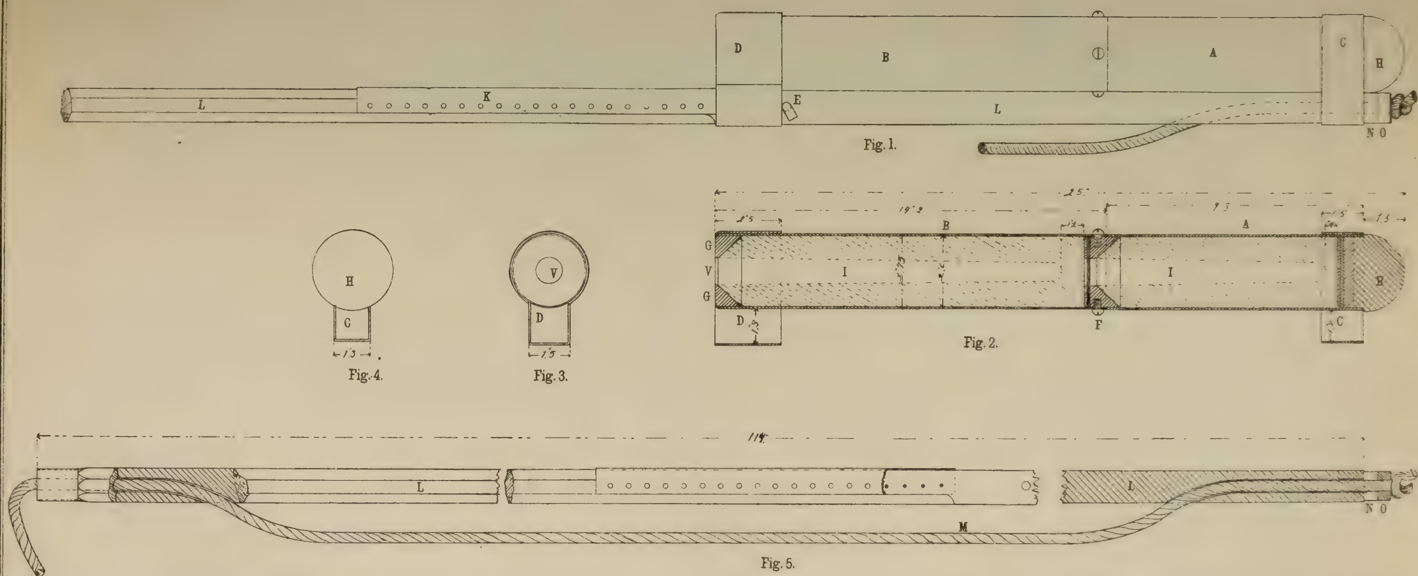


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

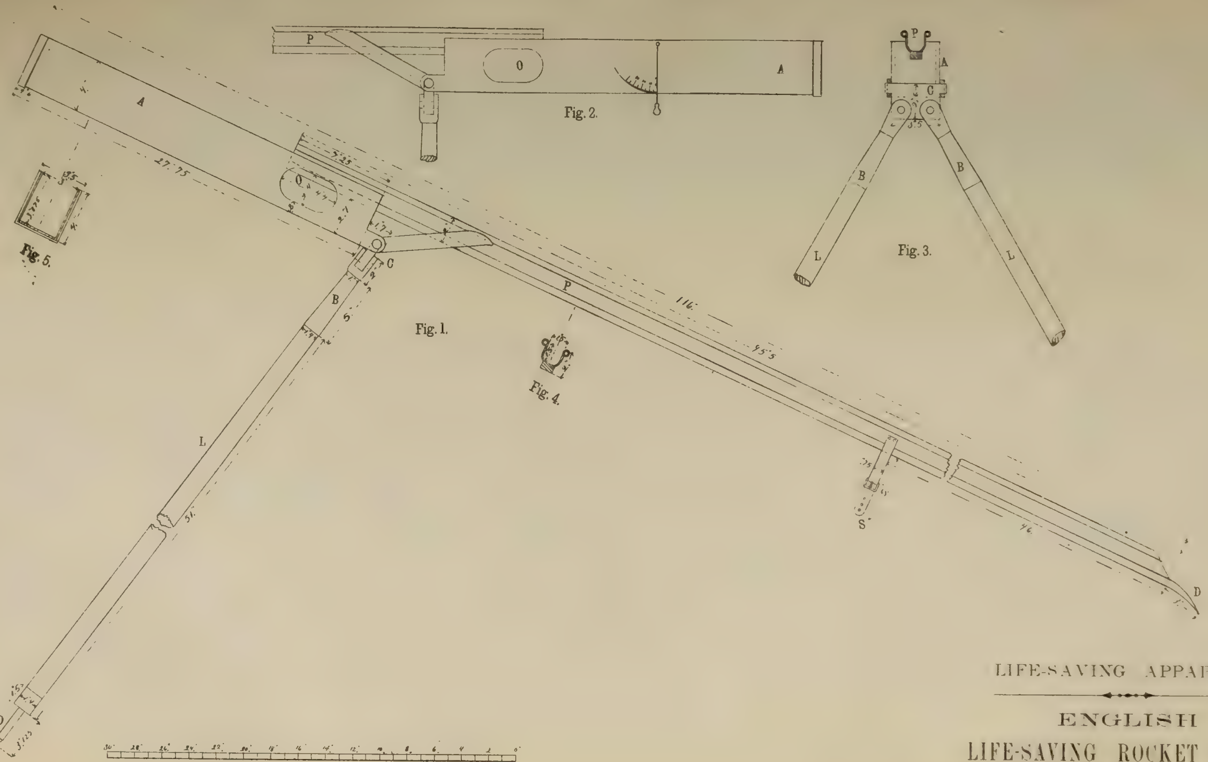
LIFE-SAVING APPARATUS.

ENGLISH LIFE-SAVING ROCKET.

AND

ROCKET STICK.

1880.



LIFE-SAVING APPARATUS.

ENGLISH LIFE-SAVING ROCKET STAND.

(Weight, 30 Pounds.)

1880.

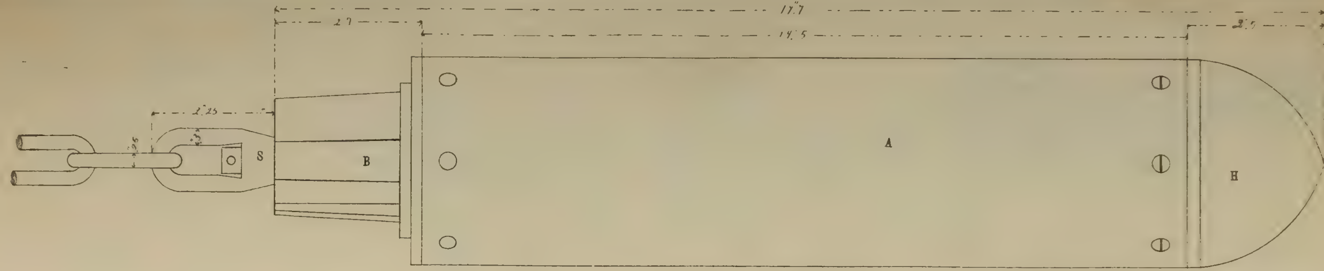


Fig. 1.

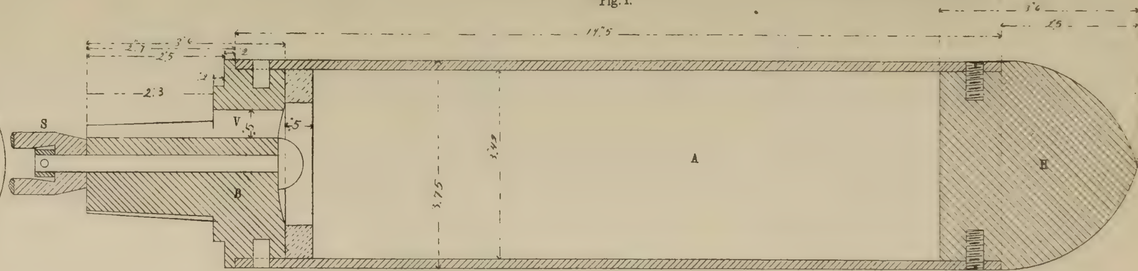


Fig. 2.

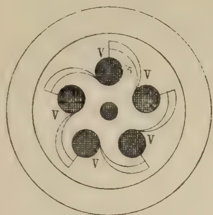


Fig. 3.

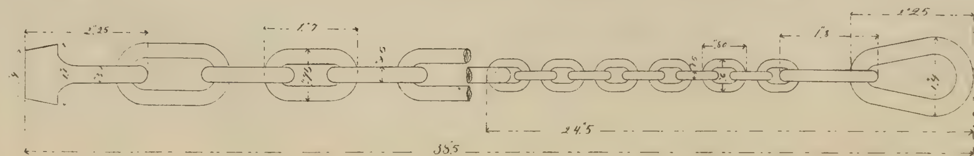
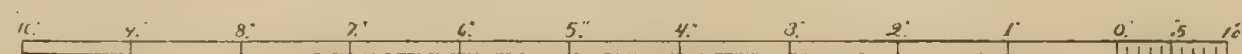


Fig. 4.



LIFE-SAVING APPARATUS.

HOOPER'S LIFE-SAVING ROCKET

And Chain, (English).

1880.

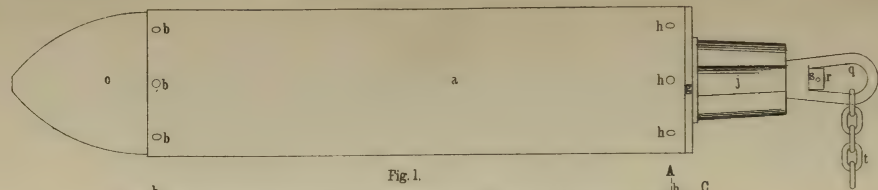


Fig. 1.

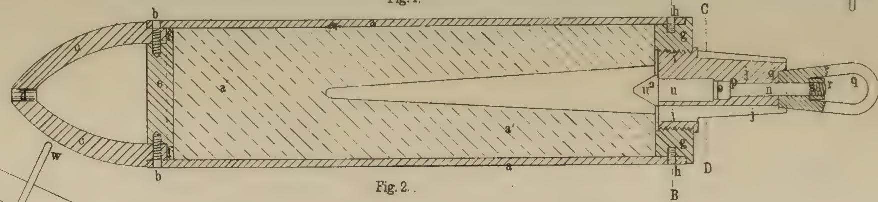


Fig. 2.

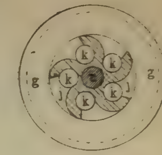


Fig. 4.

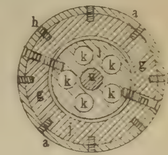


Fig. 3.

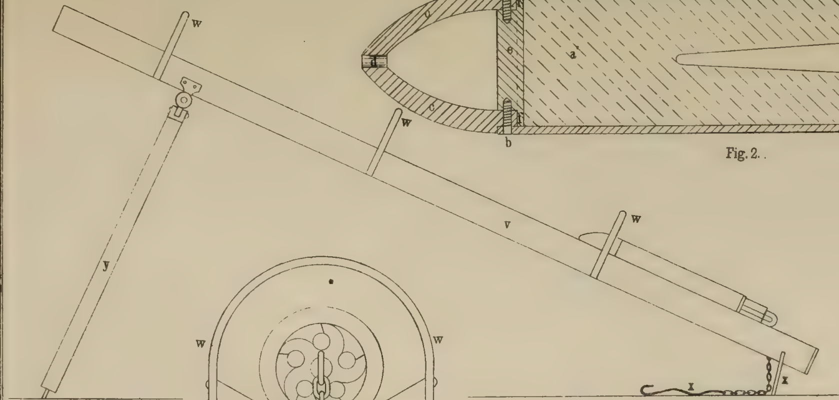


Fig. 5.

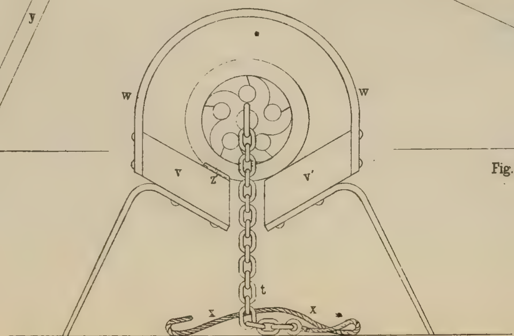


Fig. 6.

LIFE-SAVING APPARATUS.

HOOPER'S LIFE-SAVING ROCKET.

AND

Rocket Chain and Stand.

1880.

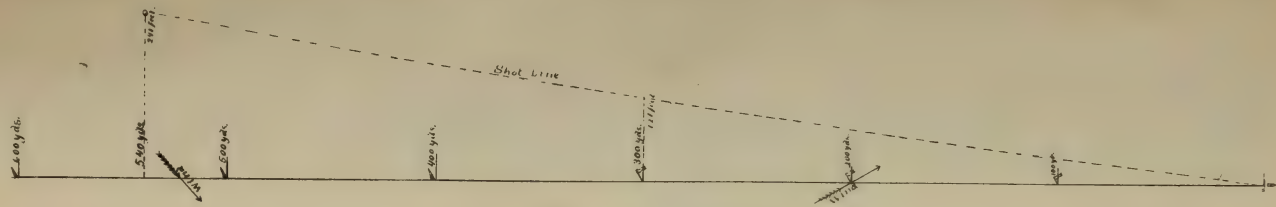


Fig. 1.

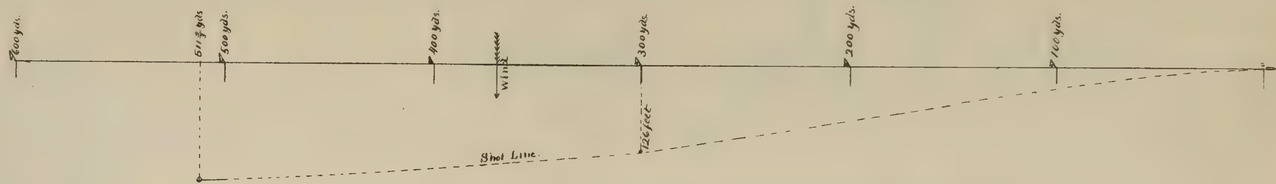


Fig. 2.

LIFE-SAVING APPARATUS.

DIAGRAMS

SHOWING

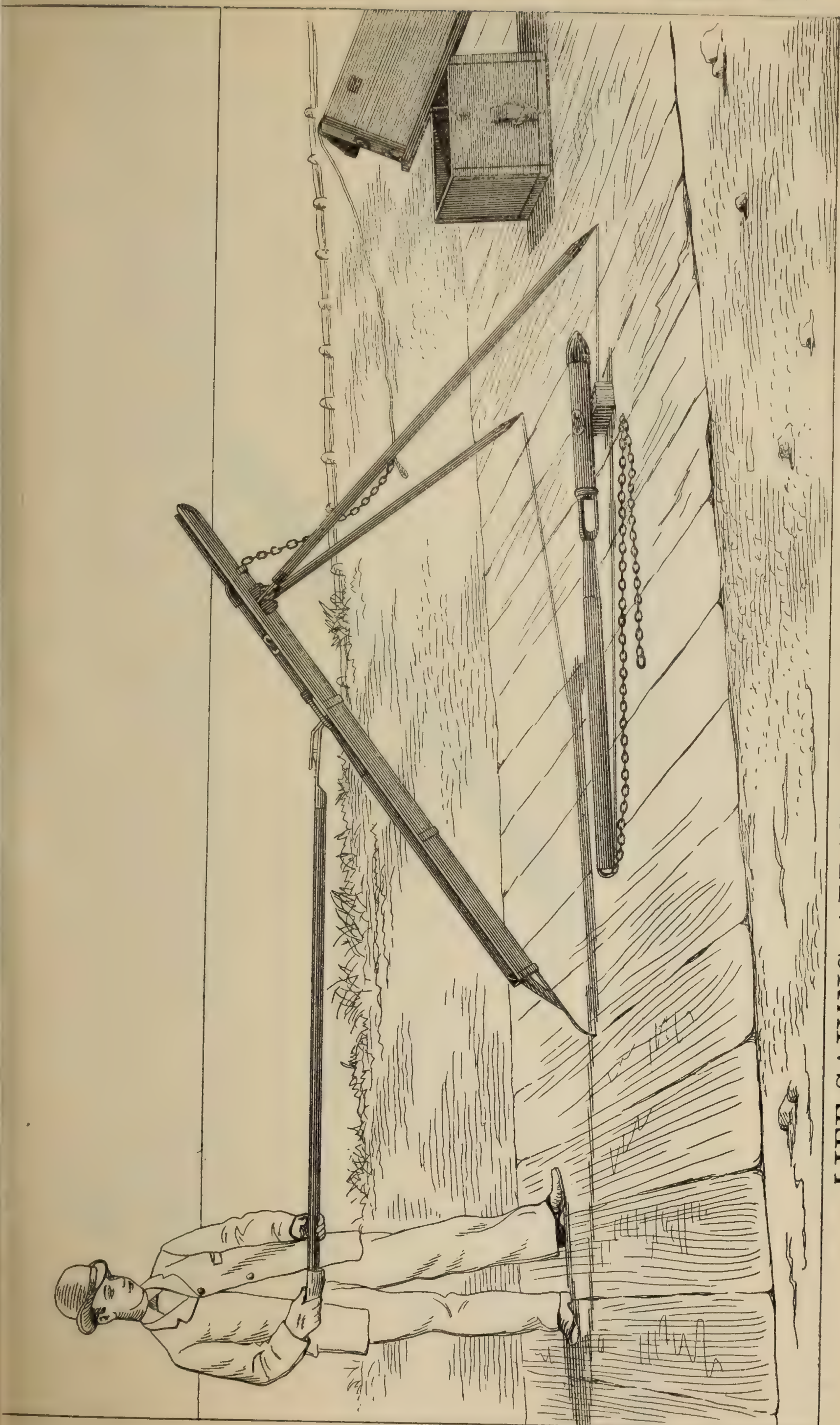
THE EFFECTS OF THE WIND

UPON THE

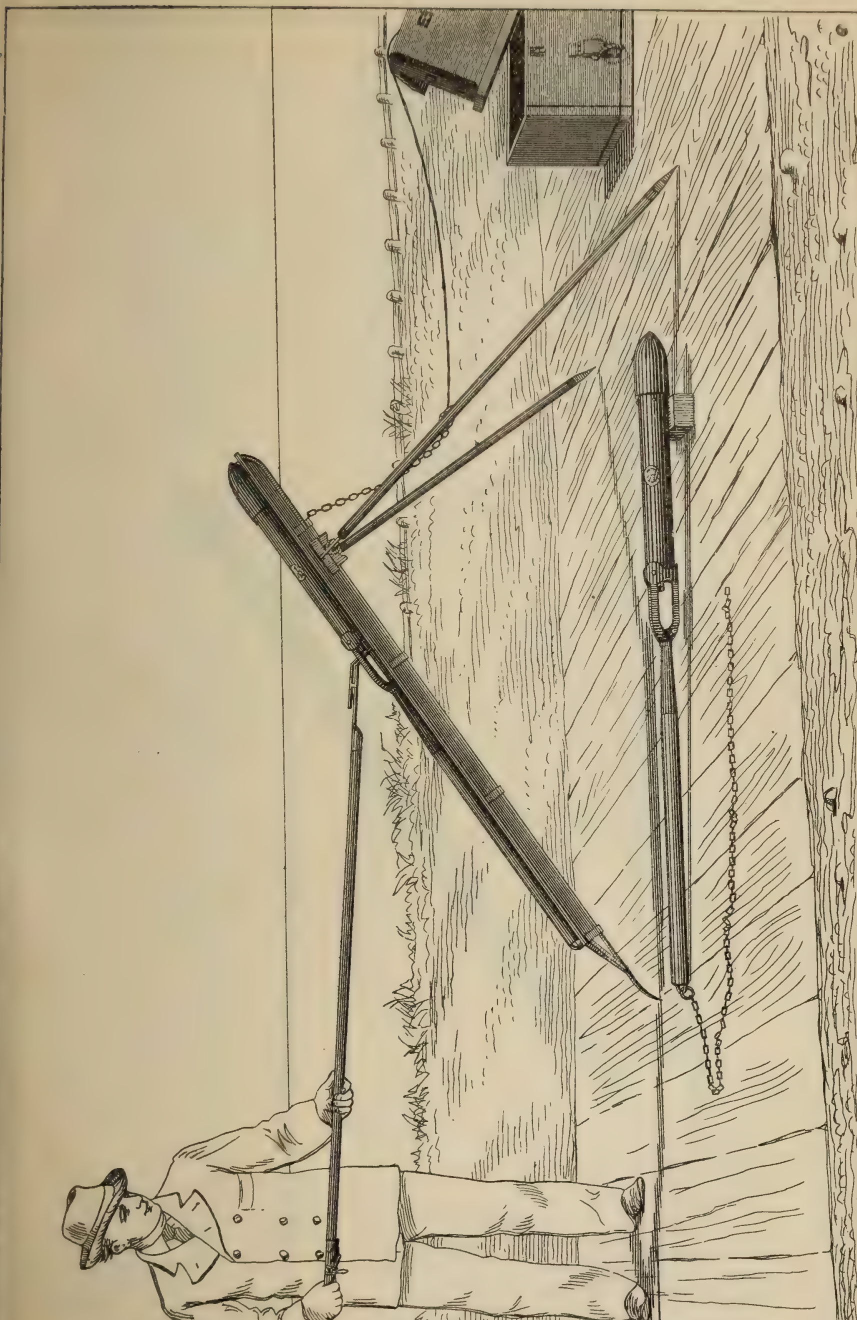
Trajectories of English Life-Saving Rockets.

1880.

LIFE-SAVING APPARATUS.—Russian Rocket System.

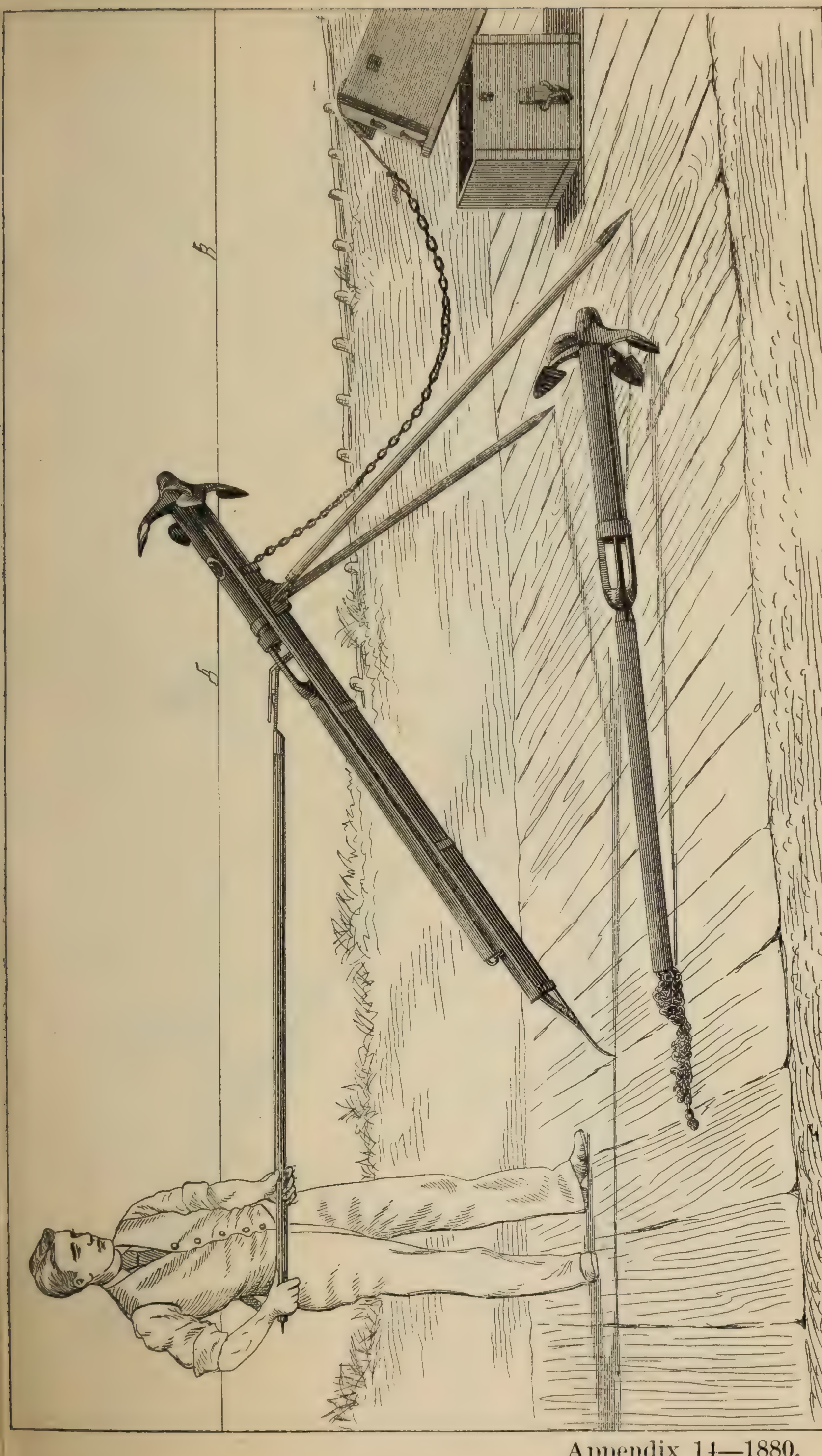


LIFE-SAVING APPARATUS.—5 cm. German Rocket System.

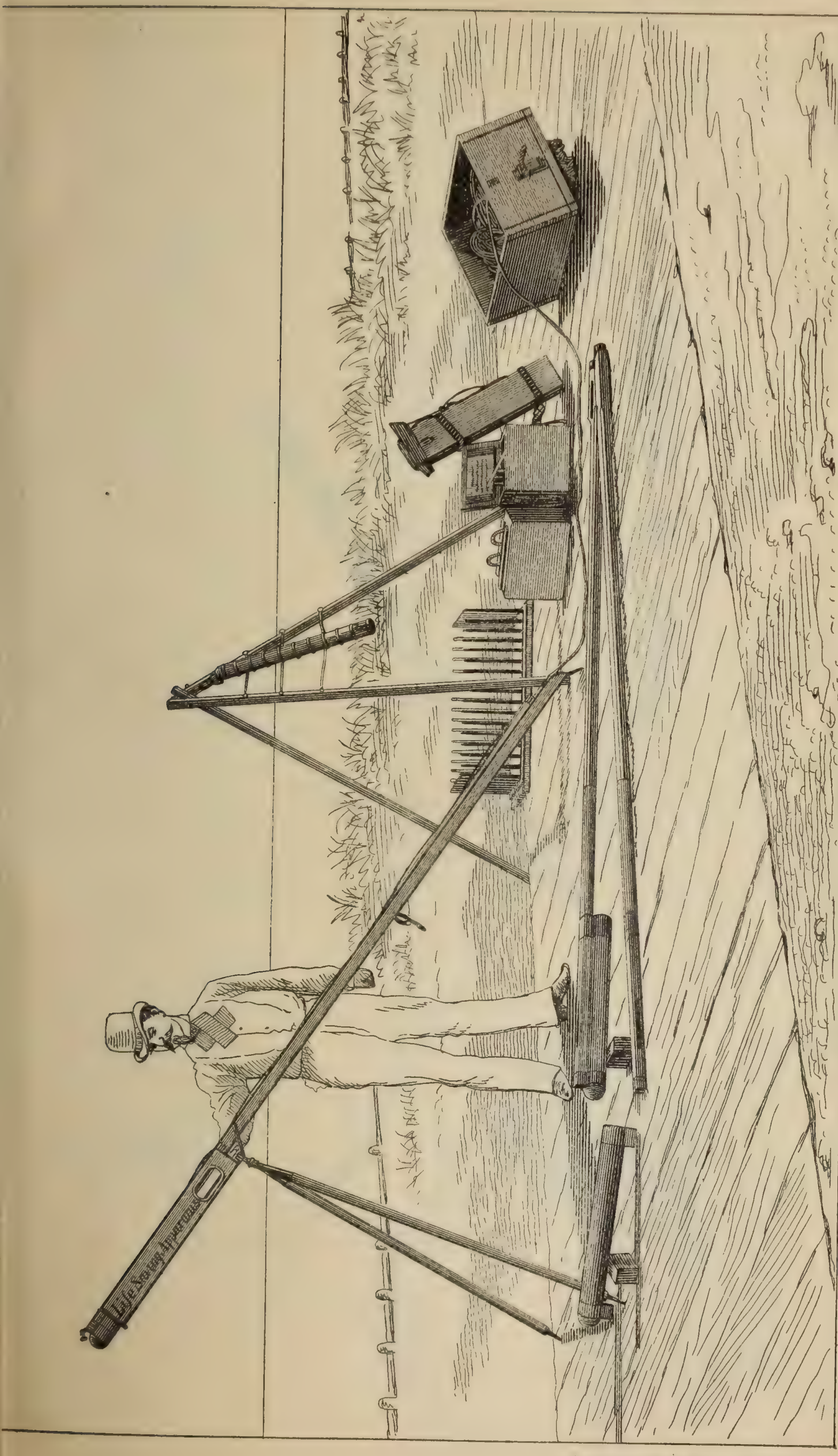


LIFE-SAVING APPARATUS.—8 cm. German Rocket System.

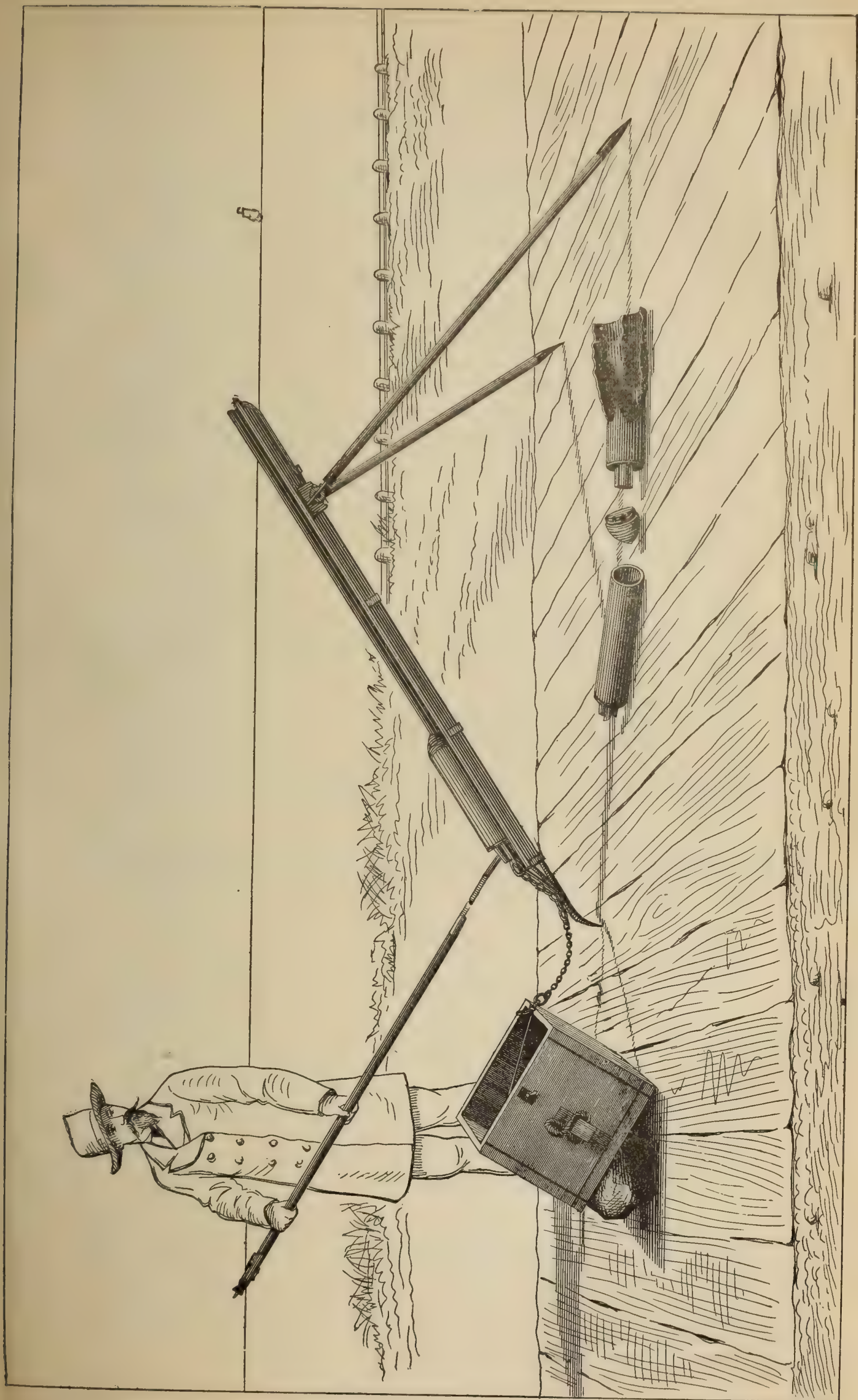
PLATE XVII.



LIFE-SAVING APPARATUS.—8 cm. German Anchor Rocket.



LIFE-SAVING APPARATUS.—English Rocket System.



LIFE-SAVING APPARATUS.—Hooper Rocket.

Appendix 14—1880.

APPENDIX 15.

DESCRIPTION OF A NEW METHOD OF FASTENING FAKING-BOXES FOR THE LIFE-SAVING SERVICE,

BY LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT.

(One plate.)

PLATE I.

The method of fastening in use in the United States life-saving service prior to 1879 was simply two staples and a hook. In transportation the hooks were liable to drop out of the engaging-staple on the box and permit the frame carrying the faking-pins and shot-line to fall to the ground and the line to become entangled.

While experimenting with life-saving apparatus during the years 1877–'78, Lieut. D. A. Lyle, Ordnance Department, U. S. A., contrived a metallic hasp and turn-button to replace the old hook and staple. In his report of 1878 he says:

> Hasps and turn-buttons were tried on the experimental boxes; these, though safe, sometimes gave trouble in getting ready for firing when in great haste, and the button being on the box, it was thought to give an opportunity for the line when vibrating or whipping to catch and be cut off.

In view of these serious disadvantages, Lieutenant Lyle devised the fastening described in this paper, and recommended that "hasps, staples, and lever snap-hooks" be tried.*

The new fastening was submitted to Capt. J. H. Merryman, U. S. R. M., Inspector, and S. I. Kimball, general superintendent of the life-saving service.

The new method was adopted, and all faking-boxes manufactured since November, 1878, have been supplied with the improved fastening.

DESCRIPTION.

The system consists of three staples, a hasp, ring, safety-chain, and lever snap-hook.

The lever snap-hooks are made of malleable iron; the two large staples and hasp of wrought iron; the small staple, ring, and safety-chain, of brass. The whole are tinned, to protect them from the effects of rust.

The only thing attached to the box is one of the large staples; consequently there is nothing on the faking-box that can interfere with or injure the line so far as the fastening is concerned.

The other parts are all attached to the "frame," and are removed with it when preparing for firing.

The safety-chain is that used by plumbers for attaching the stoppers of the exit tubes of bath-tubs and stationary wash-basins to their fixtures. It is purchased by the "piece,"* and cut into the required lengths.

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* *Vide* Report on Life-saving Ordnance, &c., by Lieut. D. A. Lyle, Ordnance Department, U. S. A., 1878, p. 28. Also Annual Report of Chief of Ordnance, U. S. A., 1878, p. 202; and Annual Report of Operations of the Life-saving Service, by S. I. Kimball, General Superintendent, 1878, p. 244.

* A "piece" is twelve feet in length.

The lever snap-hooks are known to the trade as "Andrew's patent lock-snaps, $\frac{3}{4}$-inch, No. 10," and are manufactured by O. B. North & Company, of New Haven, Conn. These snaps are put up in boxes containing "one-half gross" each.

The operation of the lever snap is very simple. The mere act of hooking the snap in the staple compresses the spring, raises the bent end of the lever, allows the staple to pass within the hook when the elastic force of the spring closes the snap, and locks it.

To remove the hook from the staple, seize the looped end with the thumb and index finger, and press them together. This action will depress the end of the lever on the opposite side of the fulcrum from the hook and unlock the snap so that it can be withdrawn from the staple. These lock-snaps were intended for the use of harness makers, and hence the lengthened slot at the end opposite the hook—which was made for the attachment of a strap or rein of a given width. This length of slot is unnecessary as regards the convenience of fastening the safety-chain and snap-hook together, but serves a most useful purpose in the life-saving service.

The excess of length of slot necessitates a corresponding amplitude of the rear end of the hook, and allows a much wider cavity for the play of the rear end of the bent lever. It also admits of this end of the lever being made spatula-shaped.

The size of the cavity and end of lever are such that the snap may be unlocked with ease by the surfman, no matter how large his thumb may be or how thick the gloves or mittens that he is wearing.

This is a point of great importance, as the surfman can manipulate this portion of the apparatus in the coldest weather without removing his hand-covering.

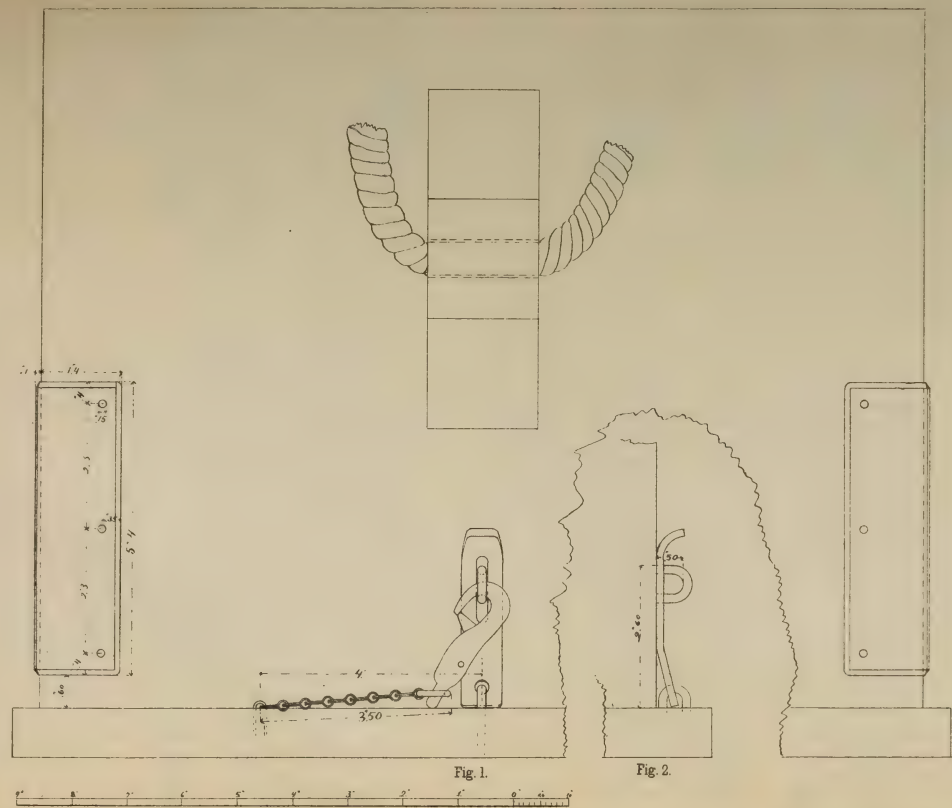
Dimensions.

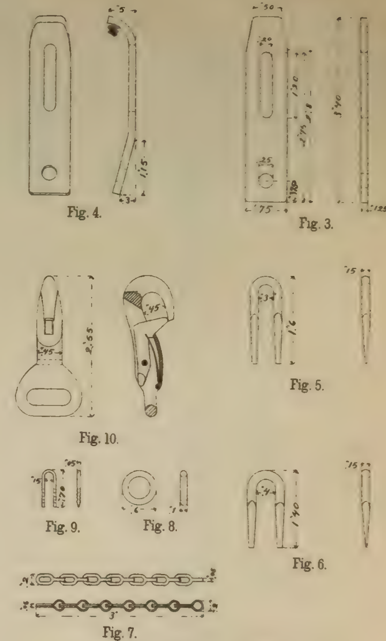
		English.	French.
		Inches.	*Centimeters.*
Hasp, total length		3.4	8.636
Length of rectangular part		2.8	7.112
Width	Lower end	0.75	1.905
	Upper end	0.50	1.27
Thickness		0.125	0.3175
Hole for staple in frame	Diameter	0.25	0.635
	Distance of center from lower end	0.375	0.9525
Slot for staple on box	Length	1.20	3.048
	Width	0.20	0.508
	Distance of upper end of slot from lower end of hasp	2.75	6.985
Length of lower end, bent		1.15	2.921
Amount of deflection		0.30	0.762
Staple for frame	Length	1.60	4.064
	Thickness	0.15	0.381
	Distance between legs	0.30	0.762
Staple for faking-box	Length	1.40	3.556
	Thickness	0.15	0.381
	Distance between legs	0.40	1.016
Staple for safety-chain	Length	0.70	1.778
	Thickness	0.05	0.127
	Distance between legs	0.15	0.381
Brass ring	Exterior diameter	0.60	1.524
	Diameter of wire	0.10	0.254
Safety-chain	Length	3.00	7.62
	Width of links	0.20	0.508
	Thickness of links	0.05	0.127
Snap-hook	Total length	2.55	6.477
	Width of body	0.45	1.143
	Distance between point of hook and body	0.45	1.143

EXPLANATION OF PLATE.

PLATE I.

FIG. 1.—End elevation of faking-box, showing manner of fastening and the "yellow metal" angle-pieces on the corners of the box.
FIG. 2.—Side elevation of hasp and large staples.
FIG. 3.—Front and side view of hasp, before curving.
FIG. 4.—Front and side view of hasp, after curving.
FIG. 5.—Front and side view of staple for "frame."
FIG. 6.—Front and side view of staple for end of faking-box.
FIG. 7.—Plan and elevation of safety-chain.
FIG. 8.—Plan and elevation of brass ring for connecting snap-hook and chain.
FIG. 9.—Front and side view of small staple for attaching safety-chain to "frame."
FIG. 10.—Plan of snap-hook, and partial section and side elevation, showing spring and bent lever.





LIFE-SAVING APPARATUS.

FASTENING FOR FAKING BOXES.

USING

Andrew's Patent Lock Snaps, 3-4 inch, No. 10.

DESIGNED BY

Lieut. D. A. LYLE, Ord. Dept., U. S. Army.

1878.

APPENDIX 16.

DESCRIPTIVE REPORT ON TWO GALVANIZED SHEET-IRON FAKING-BOXES DESIGNED FOR THE LIFE-SAVING SERVICE.

BY LIEUT. D. A. LYLE, ORDNANCE DEPARTMENT.

(Two plates.)

It has been found that the term of service of a wooden faking-box is very short. The vibrations of the line, when the full charge of powder is used, are so violent that the ends of the box are often split, and sometimes the sides and top.

It was for the purpose of preventing this splitting that angle pieces of cast brass were placed upon the four corners. Though this method of construction has remedied the defect to a certain extent, it has not fully obviated it. To secure the necessary lightness of the box, it was requisite that it be made of light wood, and that the material be very thin, consequently the box is quite fragile.

If a material can be obtained that will possess a greater degree of durability than one made of wood, and weigh no more than the latter, that material should be adopted, provided the cost of manufacture be reasonable.

The experimental faking-boxes described below were designed to meet the demands of the life-saving service for a stronger faking-box, without increasing the size, weight, or cost.

Experimental faking-box A.

Plate I.

DESCRIPTION.

This faking-box is made of "No. 24" galvanized sheet-iron. Its internal dimensions are the same as those of the regulation box. It is intended to be used in connection with the wooden frame and faking-pins now in service. The seams are at the corners and are soldered.

The edge of the box is stiffened by an iron wire, two-tenths of an inch in diameter, over which the sides and ends of the box are rolled.

Wire handles supplant the rope handles of the old box and are fastened to the box by sheet-iron straps, each held by two rivets.

A small looped strap of iron at each end of the box replaces the staples of the wooden box.

Dimensions, weight, &c.

		Inches.	Centimeters.
Interior dimensions	Length	34.9	88.644
	Width	18.8	47.751
	Depth	12.2	30.987
Thickness of sheet-iron		.02	0.0508
Diameter of perimeter wire		.20	0.508
Two straps for handles	Length	2.00	5.08
	Width	1.25	3.175
Two handles, wire-loops	Length, interior	4.60	11.684
	Width, interior	2.80	7.112
	Diameter of wire	0.25	0.635
Two looped straps (ends)	Total length	3.75	9.525
	Width	0.40	1.016
	Width of loop	0.40	1.016
	Diameter of wire	0.15	0.381
Distance from edge to upper side of loop		2.6	6.604
Distance of handle from edge of box		7.0	17.780
		Pounds.	Kilograms.
Weight of box, without frame or pins		17.5	7.932

The dimensions of the frame, false bottom, pins, &c., are the same as those in the service box.

The outside of the sheet-iron faking-box is painted in the usual manner.

COMPARISON OF WEIGHTS.

The following table gives the weights of a number of wooden faking-boxes, size A, made at the National Armory in July, 1880. The timber for these boxes was well seasoned and had laid in a warm, dry room for several months before the articles were made. It was perfectly dry, and it is evident that the boxes had their minimum weight.

TABLE I.

No. of box.	Weight.	No. of box.	Weight.	No. of box.	Weight.
	Pounds.		*Pounds.*		*Pounds.*
1	20.50	10	20.75	19	20.25
2	20.25	11	21.00	20	20.25
3	21.00	12	20.25	21	20.00
4	19.75	13	20.50	22	20.50
5	21.50	14	21.75	23	22.00
6	19.50	15	20.75	24	20.50
7	21.00	16	20.25	25	21.00
8	21.25	17	20.50		
9	21.25	18	21.25		

	Pounds.
Total weight of 25 boxes (wood)	517.5
Mean	20.7
Weight of iron box	17.5
Difference in favor of iron box	3.2

EXPERIMENTAL FAKING-BOX B.

PLATE II.

The box is similar in construction to the one previously described, but is smaller, and conforms in size to the small faking-box (B) now used.

The material is No. 27, galvanized sheet-iron. It also is painted in service colors.

Dimensions, weight, &c.

		Inches.	Centimeters.
Interior dimensions	Length	22.8	57,911
	Width	14.8	37.591
	Depth	12.2	30.937
Thickness of sheet-iron		0.16	0.406
Diameter of perimeter wire		0.20	0.508
2 straps for handles	Length	2.40	6.096
	Width	1.25	3.175
2 handles, wire loops	Length, interior	4.00	10.160
	Width, interior	2.25	5.715
	Diameter of wire	0.25	.635
2 looped straps	Total length	3.75	9.525
	Width	0.40	1.016
	Width of loop	0.40	1.016
	Diameter of wire	0.15	0.381
Distance from edge to upper side of loop		2.60	6.604
Distance of handle from edge of box		7.00	17.780
		Pounds.	Kilograms.
Weight of box, without frame and pins		10.0	4.536

COMPARISON OF WEIGHTS.

The 25 wooden boxes, size B, were made from the same lot of lumber and at the same time as those given in Table I.

TABLE II.

Number of box.	Weight.	Number of box.	Weight.	Number of box.	Weight.
	Pounds.		*Pounds.*		*Pounds.*
1	14.75	10	15.00	19	14.00
2	14.75	11	15.00	20	14.75
3	14.75	12	15.25	21	14.75
4	14.25	13	14.75	22	14.50
5	15.50	14	14.25	23	14.75
6	14.00	15	13.75	24	15.00
7	14.75	16	14.00	25	15.00
8	14.25	17	14.25		
9	14.75	18	15.25		

	Pounds.
Total weight of 25 boxes (wood)	366.0
Mean	14.64
Weight of iron box	10.00
Difference in favor of iron box	4.64

COST.

The cost of manufacture is a little less than the cost of the wooden faking-boxes of the same size.

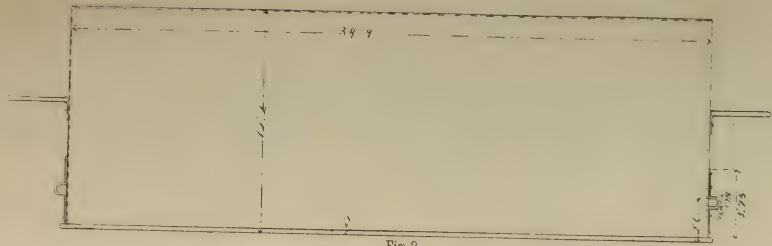


Fig. 2.

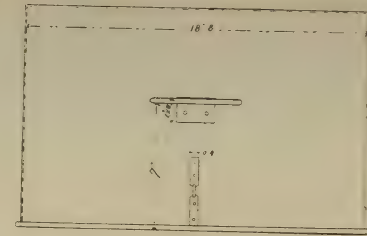


Fig. 3.

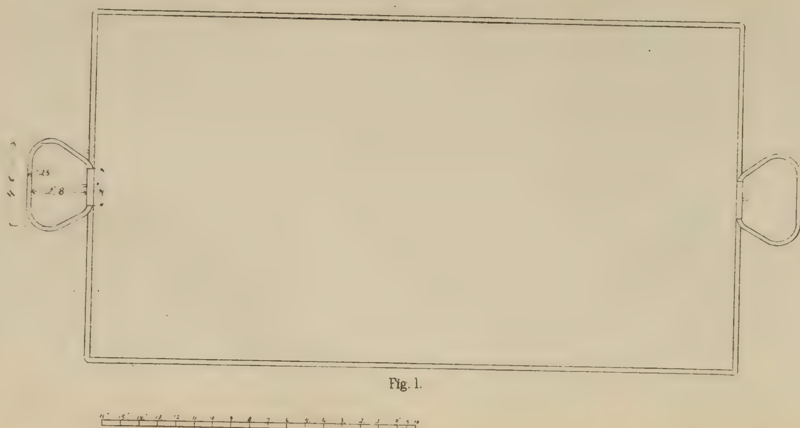


Fig. 1.

LIFE-SAVING APPARATUS.

EXPERIMENTAL FAKING BOX, "A."

— MADE OF —

Galvanized Sheet Iron, No. 24.

(WEIGHT 17.5 LBS.

REGULATION SIZE.

DESIGNED BY

Lieut. D. A. LYLE. Ord. Dept., U. S. Army.

MAY 1, 1880.

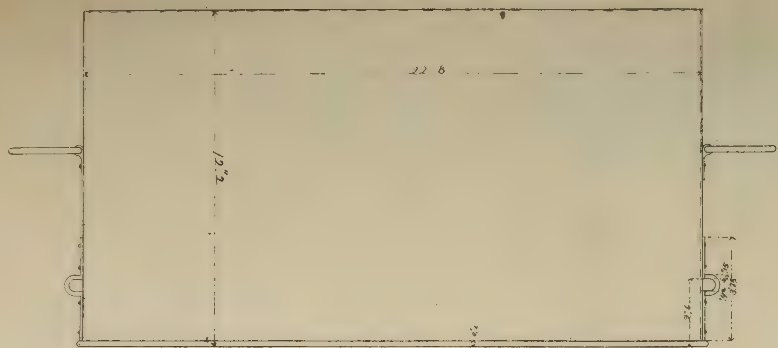


Fig. 2.

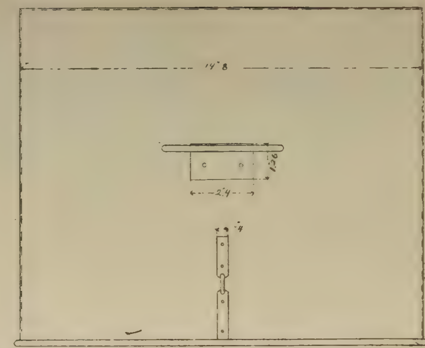


Fig. 3.

Fig. 1.

LIFE-SAVING APPARATUS.

EXPERIMENTAL FAKING BOX. "B,"

MADE OF

Galvanized Sheet Iron, No. 27.

(WEIGHT 10 LBS.)

REGULATION SIZE.

DESIGNED BY

Lieut. D. A. LYLE, Ord. Dept., U. S. Army.

MAY 1, 1880.

APPENDIX 17.

UNITED STATES TESTING-MACHINE.

[House Ex. Doc. No. 74.—46th Congress, 2d session.]

Message from the President of the United States transmitting papers in the case of A. H. Emery.

EXECUTIVE MANSION,
Washington, D. C., April 16, 1880.

To the House of Representatives:

The Board for Testing Iron, Steel, and other metals, appointed under the authority of "An act making appropriations for sundry civil expenses of the government for the fiscal year ending June 30, 1876, and for other purposes," contracted with Mr. A. H. Emery, of New York, for a testing-machine, to be paid for out of the appropriation made for the purpose. That machine has been completed and accepted, and is now in position at the Watertown Arsenal, Massachusetts. It is spoken of by the members composing the late board as the most perfect and reliable machine in the world, embodying new mechanical principles and combinations not heretofore used in any other constructions.

In designing, perfecting, and making this machine, the contractor has expended large sums of money over and above the contract price, besides giving years of labor for which he has received no compensation. He now appeals to Congress for relief, and the papers herewith exhibit a case that calls for Congressional action. It is respectfully submitted to the House of Representatives, recommending speedy and favorable consideration.

R. B. HAYES.

WAR DEPARTMENT,
Washington City, April 14, 1880.

SIR: I have the honor to return the papers in the claim of Mr. A. H. Emery.

These papers have been referred to the Chief of Ordnance, and your attention is invited to his indorsment, and to that of Colonel Laidley, president of the late Board on Steel and Iron, as well as to the views of some of the members of the board.

This is a case that calls for Congressional action. These papers show that it is one deserving favorable consideration.

The country is now in possession of the most perfect testing-machine in the world. The use of metals in all kinds of constructions, both private and public, demands so accurate a knowledge of their qualities as can only be determined by just such a machine as this, and its determinations will be of the greatest value to one of the most extensive industries in which our people are engaged.

It appears to me that liberal action on the part of Congress towards one of our own citizens who has lost so much in faithfully carrying out his contract, would be but proper and equitable.

Colonel Laidley and other members of the board, who are thoroughly cognizant of all the facts, name $200,000 as not excessive, "or more than sufficient to pay the contractor for his unusual devotion to the interests of the government."

I respectfully recommend reference of these papers to Congress with request for speedy and favorable action.

Very respectfully, your obedient servant,

ALEX. RAMSEY,
Secretary of War.

The PRESIDENT.

WASHINGTON, D. C., *March* 27, 1880.

The President of the United States:

SIR: I desire to call your attention to the letter of the president of the Board for Testing Iron and Steel of date February 10, 1878, and addressed to you, recommending Congress to appropriate moneys to reimburse A. H. Emery for losses on his contract for the testing-machine built by him for the government, and I inclose herewith additional papers, bearing on the subject, for such reference and action as you may deem proper.

Very respectfully, your obedient servant,

A. H. EMERY.

Memorial in claim of A. H. Emery for loss, allowance, and use of patents in constructing testing-machine.

In the matter of the claim of A. H. Emery against the United States Government.

WASHINGTON, D. C., *ss:*

A. H. Emery, being duly sworn, deposes and says that he is a civil engineer, of the city of New York, and that he has for the past 28 years been engaged in the study and practice of civil engineering, and most of this time engaged in such experimental work as gave him a much better training to design and construct new and difficult work than that of most engineers of his age, or equal length of practice; said deponent further states that on July 24, 1873, after he had spent more than two years in the study and experimental development of a new weighing-machine, and the study and design of testing-machines, the Ordnance Department of the United States requested him to furnish it with detailed drawings and description of a powerful machine for testing the strength, tensile, crushing, and torsional, of metals and woods, with a view to purchase by them, to which he replied on July 28, following, and immediately set to work with increased force, and the utmost diligence, to master the whole subject in such a way as to design the best machine practicable; in doing which he added to the one draftsman he then had two engineers, and that they all pushed the drawings of the studies and designs which he made of testing-machines as rapidly as possible, that he might know how best to design a machine for the government, and that before these studies were complete, and in November, 1873, he was urged to make a proposal to the said department for the machine they desired, which he did on December 10 of that year, which proposal was accepted and the machine ordered on December 24, 1873. Deponent further states that the principal things fixed in this order

were, first, the size, which was fixed at 400 net tons for loads of tension or compression, or specimens up to 30 feet in length; second, the general dimensions of some of the principal parts of the machine, and what should be furnished with it; third, the quality of the work, the tests it should bear, &c., and lastly the price, which was to be $25,000, exclusive of foundations, and that it was then supposed by him that the metal work of the machine would be about 80,000 pounds in weight when all completed. Deponent further states that the drawings of this machine were commenced at once and pushed as fast as could be done with due regard to the perfection of the work, which to bring to the point he thought desirable required altering over and over again, until in the perfecting and arranging the different parts with each other the whole machine was drawn on an average nearly or quite three times, in doing which he arrived at greater perfection of design than is usually done in building machines over many times in the shop; but he had also done two other things: first, in thus perfecting the machine he had raised its weight to nearly double that intended when it was ordered; second, he had spent upon the drawings more than four times the amount of time and money he had expected to when the design was commenced. Deponent further states that when the design was nearly made it was proposed to have a board appointed by the President to take charge of and make experiments on iron, steel, and other metals, and that he was then (in February, 1875) requested by the Chief of the Ordnance Department to go to Washington for consultation, which he did, and that he was there requested to suspend work in the shops until the question of the appointment of a board was determined, which question was settled by the appointment of a board by the President under direction of Congress, with instructions to contract for a machine, and to make experiments with a view to the formation of correct tables and formula to show the true properties and strength of materials, and that this board then took the place of the Ordnance Department as regards this machine, and the sum of $6,500 was added to said contract price for some additional apparatus, which the board desired furnished therewith, and a new contract was made therefor, thus changing the price from $25,000 to $31,500, and increasing the weight of the machine about 10 per cent., and rendering necessary some alterations in the rest of the machine, for which additional drawings were prepared, and the work pushed as rapidly as practicable Said deponent further states that as the work progressed alterations and changes in different parts thereof were found desirable and necessary, and that it became necessary to make some special tools and apparatus with which to construct and test various parts of the work, and that during and in the progress of making and testing this machine numerous difficulties came up, many parts having to be made over and over again; and that while, before designing, the machine was expected to contain about 80,000 pounds of metal, it really contains about 170,000 pounds, so much has it been improved and altered in the design and construction from what was intended when first ordered; and that owing to this change of form and size, and the numerous difficulties of construction, many parts being condemned and made over or altered, often several times, there was really put into the furnace and forges to construct this machine more than twice this 170,000 pounds, and more than four times the 80,000 pounds originally intended to be in it. Deponent also states that to save the time of explaining or even alluding to the many difficulties which came up in this construction, and yet that they may in some measure appear, and also to show how persistently and faithfully he worked for, and to what extent he overcame them, he makes the following ex-

tracts from the letter of the president of the board to the President of the United States, bearing date February 10, 1879:

> In the plans designed by Mr. Emery he adopted new principles, in the working out of which he met, as is always the case under such circumstances, with great and unlooked for difficulty. In overcoming these difficulties Mr. Emery has spent more money than he has received for the entire machine, to say nothing of his other expenses, time, labor, &c. He has throughout, in the performance of his part of the contract, shown a greater desire to make the machine perfect in all its details than to complete the work and obtain his money. The result of this unusual devotion is that the United States has at this time a more perfect machine than was called for by the terms of the contract.
>
> This machine combines the qualities of power and delicacy to an extent hitherto unknown, and is equally adapted to the testing of the ultimate strength of an iron bar 30 feet in length and 5 inches in diameter, and of a piece of wire of the finest size drawn, 1 inch long, and is capable of giving the exact strain of rupture of each. This is more than can be said of any other machine now in existence; in fact, its capabilities and the ease with which the greatest strains are applied are such as to pass even the bounds of belief of those who have not witnessed its operation.

The said deponent further states that this machine was finished and accepted by the board on February 8, 1879, though he has spent some time and money for it since, of which he mentions the furnishing, subsequent to its acceptance, of an extra set of bronze nuts at a cost of nearly $1,000, because it was found they were very much needed, and the board had no money to purchase them with, and that they are shown as a part of the cost of the machine in Exhibit N. Said deponent further states that he worked faithfully and continuously to design and produce this machine most of his time from July, 1873, to February, 1879, to the very great, and he fears permanent, injury of his health, and to the entire neglect of all business and interests not connected therewith, thus showing a direct cost of about five and one half years of his time, to which should be added at least a portion of the two years previously spent in the study and experiments of, and for scales and testing machines, which study and expense have so far been of no farther avail than the construction of this machine, to produce which he has spent, including interest paid and yet to be paid, the following sums, as shown by Exhibits A to P, inclusively, these expenditures being here shown in yearly statements, beginning with the year ending January 1, 1875, and ending with the year ending January 1, 1880, the last being that in which the machine was completed, accepted, and paid for, to the extent the contract provided; each of these yearly statements being obtained by taking from the different exhibits presented herewith the amount of payments shown in each for that year, and adding to such payments interest at the rate of 7 per cent. per annum from the time of these payments until the close of the year in which they were made, which sum is then added to the amount of expenditures previously shown, with interest for that year, which together make up the sums expended and shown by yearly statements as follows, to wit:

Prior to January 1, 1875, shown in Exhibits A, B, D, I, J, and L, the sum of $9,600.05, with $147.84 interest	$9,747 89
Interest on this one year, to January, 1876	682 35
Payments shown in Exhibits B, C, D, H, I, J, K, L, M, and P during 1875, with interest to 1876, the sum of $14,443.20, with $418.61 interest	14,861 81
Making payments and cost shown to January, 1876	25,292 05
Interest on this one year, to 1877	1,770 44
Payments shown in Exhibits B, C, D, E, F, G, H, K, L, M, O, and P during 1876, with interest to 1877, the sum of $28,157.57, with $1,373.07 interest	29,530 64
Making cost and payments shown to 1877	56,593 13

Interest on this one year, to 1878	$3,961 52
Payments shown in Exhibits B, D, F, H, K, L, M, N, O, and P during 1877, with interest to 1878, the sum of $27,895.28, with $1,218.83 interest	29,114 11
Making payments and cost shown to 1878	89,668 76
Interest on this one year, to 1879	6,276 81
Payments shown in Exhibits B, K, L, M, and N during 1878, with interest to January 1, 1879, the sum of $14,322.54, with $773.64 interest	15,096 18
Making payments and cost shown to 1879	111,041 75
Interest on this one year, to January, 1880	7,772 92
Payments shown in Exhibits D, K, L, M, N, O, and P during 1879, including previous cost not reported above, but shown in these exhibits, with interest thereon to January 1, 1880; in all, the sum of $9,387.50, with $800.53 interest	10,188 03
Making the entire cost shown, with interest up to January 1, 1880	129,002 70

While the receipts from the government on this contract have been as follows:

May 8, 1876	$6,219 00
July 22, 1876	8,646 30
March 31, 1877	9,068 47
March 17, 1877	152 39
June 29, 1877	1,266 75
February 25, 1879	6,199 48
July 2, 1879	100 00
Which was the balance due to make up the contract price, and amounts, in all, to the sum of	31,652 39
To which there should be added an interest account, made up annually at 7 per cent. to January 1, 1880, amounting to the sum of	6,518 44
Which added to the payments make	38,170 83

Which sum, being deducted from the cost shown above, leaves a direct loss of $90,831.87, besides this large loss of time, use, and loss of patents, and losses in other directions while neglecting for several years all other business interests to attend to this work. Deponent further states that this great loss of time and money has been and is still a very great hardship to himself, family, and creditors; that a small portion of this cost still remains unpaid, as shown by the exhibits, and that to meet all the rest of this loss he had to borrow the money, which he still owes, with the interest accruing at the rate of 7 per cent. per annum; and that in his opinion justice and equity alike demand that the government shall bear this loss of money, and also reimburse him for his risk as a contractor, and that he be paid for his loss of time and the use of his patents and inventions used in said machine.

He also states that as a contractor his risks were very great, and requests that the government pay to him the said direct loss of $90,831.87 and interest thereon from January 1, 1880, until paid, together with an allowance of not less than 20 per cent. of the cost of this contract, to reimburse him for losses and risks as a contractor, which 20 per cent., amounting to the sum of $25,800.54, added to the said $90,831.87 loss, make together the sum of $116,632.41, to which there should be added a liberal sum for losses of time and patents and for use of patents and inventions in this machine, and that an allowance of 50 per cent. on the cost of the work is not unusual or unreasonable in cases where few machines of a particular kind are wanted, the allowance for the use of the patents often being much more than the cost of the machines; but in this case there are several reasons why an allowance of 50 per cent. of the cost of this work would not be sufficient to properly compensate him

for the use of his inventions in this machine, of which he would mention, first, that, as has been shown, more than five years were spent in the study, design, construction, and perfecting thereof, during which time he had to neglect entirely the development of his inventions in all other directions, losing entirely his Austrian, Prussian, and Canadian patents issued on his scales, and taking this five years from the life of all his scale patents, issued in the United States, England, France, and Belgium, making them in this respect much less valuable to put into commercial use, as they will expire so much sooner now while working; and, second, the government is not using the machine at all for the purposes intended when ordered by the Ordnance Department, or for the work intended by the "Board for Testing Iron and Steel," but is using it to do the work of private parties and firms, and at such prices as tend to break up and ruin his business of building, selling, and using testing-machines; in proof of which he would state that among the parties for whom the government has thus made tests are two firms, each of which had requested him to make for them 1,000 ton machines for tension and compression for their own use, and that the government had done this work for them, as it had for others, at a price less than they could do it for themselves, if he were to give them machines and set them up free of cost, as even in this case they would have to be at the cost of providing foundations, boiler, and engine, special tools and appliances for the work, and buildings to keep and use them in, also to keep them in order and provide suitable parties to use them, while now they are merely required to pay the direct cost of making the tests after all these things are provided; and deponent further states that such use of the machine was not intended when it was ordered, and is wholly unwarranted, and is unjust to him in the greatest degree, as he has not been compensated for this machine or the use of its patents, and that such use comes by reason of an act of Congress passed while he was engaged in setting up this machine. See act of Congress approved June 20, 1878, entitled "An act making appropriations for sundry civil expenses of the government for the fiscal year ending June 30, 1879, and for other purposes," which reads as follows:

"That the Secretary of War is hereby authorized to cause the machine built for testing iron and steel to be set up and applied to the testing of iron and steel for all persons who may desire to use it, upon the payment of a suitable fee for each test, the table of fees to be approved by the Secretary of War and to be so adjusted from time to time as to defray the actual cost of the tests as near as may be; and in order to make the final payment on contract for the construction of this machine the sum of six thousand two hundred and ninety-nine dollars and forty-eight cents of the unexpended balance now remaining on the books of the Treasury of the appropriation for this purpose is hereby reappropriated and made available therefor."

And deponent further states that such use of this machine tends to hinder and prohibit the said parties and others from purchasing machines of him, or, if they still get them, they will only do so at very low prices, in consequence of the manner and rates prescribed for the use of this machine; and that he can, for this reason, not only sell a less number of machines, and at lower prices, than he otherwise would, but must also build them at an increased cost of each, owing to the smaller production. And he further states that had he known at the outset the great amount of time this machine would consume in its construction, and what unfair use the government would make of it, he would not have built it for the government, even though it had offered to pay three

times what the same should cost, and that, should the government pay him, in addition to the said $116,632.41 for losses and allowance, as above mentioned, a sum equal to the direct cost of this work, as $129,002.70, for loss of time and use of patents, making, with the other said sum, the amount of $245,635.11, he would have been much better off financially to have left this contract alone and spend the time and money which he spent upon it in the development of his scales, &c., and that Congress should not only pay him the losses and allowance, as above mentioned, together with an equitable sum for his loss of time and use of patents, but they should also allow the patent issued on the scale of this machine to be extended for seven years to compensate in some measure for the loss of time not used in developing and working it while he was on this contract. And that, as regards the money payment to him, he would much rather, for moneys lost, allowance on contract, use of patents in this machine, and to cover the losses which directly flow from the order of Congress quoted above, giving the public the free use of this machine on the payment of nominal fees, receive *now* the sum of $200,000 than to wait longer and have his business continue in its present embarrassed condition, even were he to get a much larger sum by waiting the action of another Congress or the Court of Claims.

A. H. EMERY.

Subscribed and sworn to before me this 24th day of March, 1880.
[SEAL.] V. McNALLY,
Notary Public.

A.—*Cost of drawings made prior to October* 1, 1874.

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

A. H. Emery and O. C. Woolson, both being severally and duly sworn, say that on or about October 1, 1874, they together made an estimate of the cost of the drawings at that time made for the testing-machine built by A. H. Emery for the United States Government, and there was then made and nearly finished fifty-two sheets of these drawings, and that forty-three sheets of them had been copied on tracings linen, and that the cost of these drawings and tracings was then estimated to be as follows, to wit:

Fifty-two sheets of dawings	$7,760
Forty-three sheets of tracings	688

Making the total cost of drawings and tracings together the sum of $8,448 (eight thousand four hundred and forty-eight dollars), and that the following is a correct list of the drawings and tracings embraced in the above estimate, to wit:

Mark of plate.

Pl. 30. T. M. 5. General drawings of holders.
Pl. 31. T. M. 5. Details of holders. Top beams Nos. 1 and 2.
Pl. 32. T. M. 5. General drawings of 20″ press.
Pl. 33. T. M. 5. Details of holders (intermediate pieces).
Pl. 34. T. M. 4. Details of holders (bottom pieces and beam block).
Pl. 35. T. M. 5. Details of span-wheels for 20″ press (first driver).
Pl. 36. T. M. 5. Details of forgings for holder and press, pins, and piston rod.
Pl. 37. T. M. 5. 13″.7 hydraulic support (No. 15) for 400-ton scale.
Pl. 38. T. M. 5. Details of 20″ press (cylinder head, &c.).
Pl. 39. T. M. 5. Details for beams for 400-ton machine.
Pl. 40. T. M. 5. General drawings of scale end of 400-ton machine.
Pl. 41. T. M. 5. Details of large screws, their bearings and nuts.
Pl. 42. T. M. 5. Details of press cylinder No. 83 and press compression block.
Pl. 43. T. M. 5. Details of press truck.
Pl. 44. T. M. 5. Details of press truck.
Pl. 45. T. M. 5. First general drawings of machine.

Pl. 46. T. M. 5. General drawings of holder truck.
Pl. 47. T. M. 5. General drawings for driving head for 20″ press and details of bed-plate.
Pl. 48. T. M. 5. Details for forgings for scale end of machine.
Pl. 49. T. M. 5. General drawings of R. 6. H. S. 6.
Pl. 50. T. M. 5. General drawing of automatic screw support.
Pl. 51. T. M. 5. Main stanchion at scale end of machine.
Pl. 52. T. M. 5. General drawings of automatic shaft support.
Pl. 53. T. M. 5. Details of bed-plate for beam stanchion.
Pl. 54. T. M. 5. Details of holder truck.
Pl. 55. T. M. 5. H. S. 6.—H. S. S. 15. Details of hydraulic scale support.
Pl. 56. T. M. 5. H. S. 6.—H. S. S. 15. Details of hydraulic scale support.
Pl. 57. T. M. 5. R. 6. H. S. 6. Details of reducer.
Pl. 58. T. M. 5. R. 6. H. S. 6. Details of reducer.
Pl. 59. T. M. 5. Details of anchor plates for foundations.
Pl. 60. T. M. 5. Details of automatic shaft support.
Pl. 61. T. M. 5. H. S. 6. General drawing of upper part of scale.
Pl. 62. T. M. 5. Details of automatic screw supports.
Pl. 63. T. M. 5. General drawing of left-hand end of scale-beam, &c.
Pl. 64. T. M. 5. General drawing of right-hand end of scale-beam, &c.
Pl. 65. T. M. 5. General drawings of buffer.
Pl. 66. T. M. 5. Details of driving head from plate 47.
Pl. 67. T. M. 5. Details of main track.
Pl. 68. T. M. 5. Details of driving head from plate 47.
Pl. 69. T. M. 5. Connected drawing of levers for making weights.
Pl. 70. T. M. 5. General plan of 400-ton machine on large sheet.
Pl. 12. G. G. T. M. 5. General drawing of hydraulic gauge.
Pl. 13. G. R. 5. T. M. 5. Reducer with its details.
Pl. 14. G. V. C. 1. T. M. 5. Two 20″ hydraulic gauges in case.
Pl. 15. G. V. C. 1. T. M. 5. Details of piping and valves.
Pl. 16. G. V. C. 1. T. M. 5. Gauge valves connections with levers.
Pl. 17. G. V. C. 1. T. M. 5. Connected drawing of pipes, valves, and rods.
Pl. 18. G. 9. V. C. 1. T. M. 5. Details of Pl. 14. of 20″ hydraulic gauge.
Pl. 19. G. 9. V. C. 1. T. M. 5. Details of hydraulic gauges of plate 12.
Pl. 20. G. V. C. 1. T. M. 5. Details of 20″ hydraulic gauge, case No. 22.
Pl. 21. G. 9. 1. T. M. 5. Cast-iron case for 20″ hydraulic gauge No. 12.
Pl. 22. G. 9. T. M. 5. Detail drawing of wood case for two 20″ g.

Total 52 sheets, with tracings on linen of all these except Nos. 14, 45, 61, 62, 66, 67, 68, 69, and 70, in all 43 sheets of tracings.

A. H. EMERY.
O. C. WOOLSON.

Sworn to before me this 29th day of January, 1880.

[SEAL.] HAROLD SMITH,
Notary Public, New York County.

UNITED STATES ENGINEER OFFICE,
New York, January 30, 1880.

This is to certify that I have examined the inclosed or within list of drawings, and from what I know of their quality, and of the study and time required to produce them, I am convinced that the estimated cost, as here given, is not too high, and that they could not have been produced for a less sum.

Q. A. GILLMORE,
Lieutenant-Colonel Engineers, Brevet Major-General.

B.—*Salary of O. C. Woolson subsequent to October* 1, 1874.

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

O. C. Woolson, a mechanical engineer and draughtsman of Newark, N. J., being duly sworn, says that he was employed by A. H. Emery, of New York City, most of the time from August 16, 1873, to October 1, 1874, on drawings of his testing-machines, scales, and gauges, and that subsequent to this date he continued in his employ for three years, one and two-thirds months, or until November 20, 1877, and that during two years and ten and two-thirds months of this time he was engaged in making drawings of the testing-machine which the said Emery was building for the United

States Government, together with drawings of the scale, gauges, and other apparatus connected therewith, and of tools and apparatus to be used in the constructing and testing thereof, and in superintending the construction of this work in the shop, and in making experiments and tests connected with the said machine, and that of the time so employed subsequent to October 1, 1874, for two years and one-half his salary was $2,400 per year, and that for the other four and two-thirds months his salary was at the rate of $2,000 per year, making in all for the said two years, ten and two-thirds months the sum of $6,777.77, all of which he states has been paid to him by the said Emery as follows, to wit:

On December 31, 1874	$436 38
During February, 1875, at different dates	124 50
During April, 1875, at different dates	252 75
During May, 1875, at different dates	507 00
During June, 1875, at different dates	40 50
On July 16, 1875	200 00
During August, 1875, at different dates	150 00
During September, 1875, at different dates	70 00
On October 1, 1875	200 00
On October 25, 1875	150 00
On November 23, 1875	300 00
During January, 1876, at different times	200 00
During February, 1876, at different times	200 00
During March, 1876, at different times	155 00
During April, 1876, at different times	58 80
During May, 1876, at different times	280 00
During June, 1876, at different times	75 00
During July, 1876, at different times	123 37
On August 5, 1876	300 00
On September 5, 1876	5 00
On October 13, 1876	100 00
During November, 1876, at different dates	95 00
During December, 1876, at different dates	72 00
During January, 1877, at different dates	42 00
During February, 1877, at different dates	280 00
On March 31, 1877	100 00
On April 9, 1877	400 00
During June, 1877, at different dates	40 00
During July, 1877, at different dates	483 58
On August 31, 1877	40 00
During September, 1877, at different dates	107 00
During October, 1877, at different dates	45 00
During November, 1877, at different dates	46 00
On December 22, 1877	40 00
And on January 12, 1878, the balance	1,058 89
Making in all the sum of	6,777 77

(Six thousand seven hundred and seventy-seven and $\frac{77}{100}$ dollars.)

O. C. WOOLSON.

Sworn to before me this 29th day of January, 1830.

[SEAL.]

HAROLD SMITH,
Notary Public, New York County.

C.—*Salary of L. Hailer, draughtsman and engineer.*

In the matter of the claim of A. H. Emery against the United States Government.

ITY, COUNTY, AND STATE OF NEW YORK, *ss:*

O. C. Woolson, of Newark, N. J., being duly sworn, says he was engaged as a raughtsman and superintendent for A. H. Emery, of New York, for several years, and hat from May 19, 1875, to June 4, 1876, Mr. L. Hailer, a civil engineer, was at work n the employ of said Emery at a salary of $1,500 per year as draughtsman, and that uring eleven and and one-half months of this time the said Hailer was engaged in naking drawings of the testing-machine built by the said Emery for the United States overnment, together with drawings of its scales, gauges, and apparatus pertaining hereto, and tools and apparatus to be used in the constructing and testing of said nachines, and in testing the accuracy of parts of this work in the shop, and in the onstruction and testing the dimension gauges and tin plates therefor.

And he further states that on or about June 8, 1876, the said Hailer was discharged and fully paid, and that soon after this the said Hailer left the country for, as he supposes, his home in Germany, and that he does not know where he now is, and thinks he is in Japan. He also states that the books of the said Emery show that for the said eleven and a half months' services rendered as above stated the said Hailer was paid the following sums at the times herein stated, to wit:

During June, 1875, at different times	$45 00
During July, 1875, at different times	80 00
During August, 1875, at different times	65 00
During September, 1875, at different times	75 00
During October, 1875, at different times	157 00
During November, 1875, at different times	90 00
During December, 1875, at different times	70 00
During January, 1876, at different times	290 00
During February, 1876, at different times	70 00
During March, 1876, at different times	60 00
During April, 1876, at different times	10 00
During May, 1876, at different times	140 00
And on June 8, 1876	285 50
Making in all the sum of	1,437 50

(Fourteen hundred and thirty-seven and $\frac{50}{100}$ dollars.)

O. C. WOOLSON.

Sworn to before me this 29th day of January, 1880.

HAROLD SMITH,
Notary Public, New York County.

D.—*Rent of office.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

W. J. Dewey, being duly sworn, says he was for several years in the employ of Edward Mathews as a bookkeeper or clerk, and that he now is employed in a like capacity for the Charter Oak Life Insurance Company, and that from October 1, 1874, to February 1, 1877, A. H. Emery, a civil engineer in said city, occupied an office in the building Nos. 78 and 80 Broadway, at a yearly rental of $450 per year from October 1, 1874, to May 1, 1875; of $425 per year from May 1, 1875, to May 1, 1877, and of $325 per year from May 1, 1877, to February 1, 1879, all of which rents were due and payable quarterly unto the said Edward Mathews until and during the quarter ending May 1, 1877; and all of said rents accruing subsequent thereto were due and payable to the Charter Oak Life Insurance Company; and the said Dewey says that the said Emery paid for such rent to the said Edward Mathews, or to his agents, the following sums, and at the times herein mentioned, to wit:

On December 31, 1874, rent due November 1, with interest	$37 95	
On April 1, 1875, one quarter, to February 1, $112.50, with interest, $1.31	113 81	
On July 28, 1875, one quarter, to May 1, 1875	112 50	
On October 1, 1875, one quarter, to August 1, 1875	106 25	
On March 22, 1876, one quarter, to November 1, 1875, with interest	108 11	
On June 9, 1876, two quarters, to May 1, 1876, with interest	215 15	
On May 17, 1877, on account	200 00	
And on June 30, 1877, balance in full to May 1, 1877	212 83	
Making in all to Edward Mathews the sum of		$1,106 60
Besides which there is now due from the said Emery to the said Charter Oak Life Insurance Company for said rent from May 1, 1877, to February 1, 1879, at $325 per year, payable quarterly—seven quarters	568 75	
On which there is also due for interest thereon accrued up to January 1, 1880	66 65	
Making, together with the rent due		635 40
And with that paid		1,742 00

And the said Dewey also says that he understood and believes the business of the said Emery during this time, and for some time previous thereto, was designing and building a testing-machine for the United States Government.

WM. J. DEWEY.

Sworn to before me this 29th day of January, 1880.
[SEAL.] HERBERT S. OGDEN,
Notary Public, King's County. (*Certificate filed in New York County.*)

E.—*Bill for hydraulic pump.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

C. E. Bigelow, manager for the Knowles Steam-pump Company, being duly sworn, says that during the years 1875 and 1876 there was built by contract with and for A. H. Emery, of New York City, a *double double-acting* hydraulic pump to go with the testing-machine the said Emery was then building for the United States Government, and that said pump was built by the said Knowles Steam-pump Company at their works at Warren, Mass., and delivered on board the cars at that place, for the sum of $637.38 (six hundred and thirty-seven and thirty-eight hundredths dollars), which sum was paid by the said Emery to the said pump company on September 19, 1876.

C. E. BIGELOW.

Subscribed and sworn to before me this 29th day of January, 1880.
[SEAL.] DAVID J. H. WILLCOX,
Notary Public for Richmond County. (*Certificate in New York County.*)

F.—*Bill of Colonel Laidley.*

In the matter of the claim of A. H. Emery against the United States Government.

I hereby certify that the following accounts were paid by Mr. A. H. Emery on the dates mentioned, for labor and material, on account of the construction of the testing-machine erected at this arsenal:

October 2, 1876. A. T. Brewer, labor	$15 12	
October 2, 1876. J. G. Campbell, labor	101 06	
October 2, 1876. J. W. Harvey, labor	101 75	
		$217 93
April 7, 1877. W. A. Martin, screws	3 30	
April 7, 1877. Stetson & Pope, hard pine lumber	199 28	
		202 58
July 3, 1877. J. L. Sands, brick	42 00	
July 3, 1877. J. G. & N. G. Gooch, cement	33 30	
		75 30
Total		495 81

T. T. S. LAIDLEY,
Colonel of Ordnance, Commanding.

WATERTOWN ARSENAL, *February* 13, 1880.

G.—*Bill of Charles E. Emery.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

Charles E. Emery, an engineer, in the city of New York, being duly sworn, says that in June, 1875, he sold unto A. H. Emery, of said city, an invention which the United States board for testing iron and steel desired him to introduce in the testing-machine he was then building for the United States Government, which invention was for the

purpose of neutralizing the packing friction in hydraulic presses and gauges, and was to be used in that part of the machine known as the diagram apparatus, and that for the right to use the said invention in the said machine, and in another machine which he might design and build to take the place thereof, he was to pay deponent the sum of $2,000 (two thousand dollars), which sum he did pay to him on February 21, 1876.

CHAS. E. EMERY.

Sworn to and subscribed before me this 29th day of January, A. D. 1880.
[SEAL.] LEONARD A. GIEGERICH,
Notary Public, New York County.

H.—*Salary of S. Cockshaw.*

In the matter of the claim of A. H. Emery against the Government of the United States.

CITY AND COUNTY OF NEW YORK, *ss:*

Sidney Cockshaw, being duly sworn, says that he is a mechanical draftsman, of New York City, and was employed by A. H. Emery, of said city, as a draftsman, from April 21, 1875, until June 2, 1877, 611½ days, of which 575.5 days were spent upon drawings of the testing-machine which he was then building for the United States Government, and upon the scales, gauges, apparatus, and tools connected therewith, or to be used in the construction and testing thereof, for which services I was paid the sum of three dollars per day, making for the said 575½ days the sum of $1,726.50 (seventeen hundred and twenty-six and one-half dollars), which sum was paid to me as follows, to wit:

During May and June, 1875	$60 00
During July, August, and September, 1875	155 00
During October, November, and December, 1875	275 00
During January, February, and March, 1876	175 00
During April, May, and June, 1876	194 00
During July, August, and September, 1876	180 00
During October, November, and December, 1876	205 00
During January, February, and March, 1877	155 50
During April, May, and June, 1877	130 00
During July, on and before the 16th, 1877	197 00
Making in all the sum of	1,726 50

as above mentioned.

SIDNEY COCKSHAW.

Sworn to before me this 23d day of January, 1880.
[SEAL.] WM. PEET, JR.,
Notary Public, Kings County. (*Certificate in New York County.*)

I.—*Salary of M. Randolph.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

M. Randolph, of the city of New York, being duly sworn, says that he was employed by A. H. Emery, of said city, as a draftsman, from July 19, 1873, to August 7, 1875, at work on his testing-machines, scales and gauges therefor, and that subsequent to October 1, 1874, he was thus employed on the testing-machine built by the said Emery for the United States Government, together with its scale and gauges, two hundred and twenty-five days at $4 per day, for which services he was paid by the said Emery as follows, to wit:

During October, November, and December, of 1874, the sum of	$300 00
During January, February, and March, 1875	247 00
During April, May, and June, 1875	257 00
During July and August 7, 1875	96 00
Making in all the sum of (nine hundred dollars)	900 00

M. RANDOLPH.

Sworn to before me this 29th day of January, 1880.
[SEAL.] L. RINDSKOPF,
Notary Public, New York.

J.—*Salary of Eugene J. Jerzmanowski.*

In the matter of the claim of A. H. Emery against the Government of the United States.

To whom it may concern:

I hereby certify that I, Eugene J. Jerzmanowski, am an engineer and draftsman, and was in the employ of A. H. Emery, of New York City, as a draftsman most of the time from August 4, 1873, to March 30, 1875, on drawings of his testing-machine, scales, and gauges; and that subsequent to October 1, 1874, and between this time and March 30, 1875, I was employed on drawings of the testing-machine he built for the government, or on its scale and gauges, for the period of eighty-three days, at a salary of $4 per day, for which I received payment as follows, to wit:

On December 31, 1874	$220 00
On February 13, 1875	72 00
On April 21, 1875	40 00
Making in all the sum of (three hundred and thirty-two dollars)	332 00

Given under my hand this 22d day of January, 1880.

EUGENE J. JERZMANOWSKI.

STATE OF NEW YORK,
City and County of New York, ss:

On this 22d day of January, 1880, personally appeared before me Eugene J. Jerzmanowski, known to me to be the individual described in and who executed the foregoing instrument, and acknowledged that he executed the same and that its contents were true.

[SEAL.]

HAROLD SMITH,
Notary Public, New York County.

K.—*Salary of A. H. Emery.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

A. H. Emery, being duly sworn, deposes and says that he is a civil engineer of the city of New York, and that from December, 1873, until February 10, 1879, he was engaged in designing, constructing, testing, and other work connected with the testing-machine which he designed, built, and erected at Watertown Arsenal, Massachusetts, and that he would not devote his time to any enterprise for the sum of $5,000 per year, as he could not do so without neglecting valuable enterprises by which he would suffer large loss from the non-development thereof; but as a contractor to furnish said machine, it was necessary to employ some one to design and superintend the construction and testing thereof, and that he had been unable to employ any other suitable party to do this work, and had, therefore, attended to it himself, as above stated, and that he does not know or believe any suitable party could have been employed to do this work for the said $5,000 per year, and this sum should be allowed to him as a salary to partially compensate him for his time while so engaged. And deponent further states that said sum should be considered, and is, a part of the direct cost of the machine, and is included for nine months from December, 1873, to October 1, 1874, in the cost of drawings shown in Exhibit A, and that no part thereof is shown in any other exhibit than this, and that the remainder of this said $5,000 per year from October 1, 1874, to February 10, 1879, amounts to the sum of $21,805.55 (twenty-one thousand eight hundred and five and $\frac{55}{100}$ dollars), and should, in making up the interest account, be considered as due, and paid quarterly during this time, and that while this sum is not sufficient to compensate him for his time, as shown above, it was really insufficient to cover his necessary expenses incurred during this period in connection with the inventions used in said machine, and for the necessary expenses of himself and family while he was so engaged, so that in allowing this sum as a part of the cost of this machine, he still loses his time from the development of his other enterprises, and is thereby a large loser, as shown above.

A. H. EMERY.

Sworn to before me this 20th day of March, 1880.

[SEAL.]

HAROLD SMITH,
Notary Public, New York County.

L.—*Bill of sundries.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

A. H. Emery, being duly sworn, deposes and says that he designed and constructed for the United States Government a testing-machine which was erected at Watertown Arsenal, Massachusetts, and that in the prosecution of this work he incurred various sundry expenses connected therewith, such as traveling expenses, freights, timber for use in connection therewith, testing, &c., hydraulic piping, steam and oil piping, and fittings, packing lathes, lining cylinder of straining press, office expenses, gauges, copper piping, &c., amounting in the aggregate to the sum of $3,441.83 (three thousand four hundred and forty-one and $\frac{83}{100}$ dollars), and that all these expenses are given and shown in detail in the statement inclosed herewith, and were for the purposes mentioned herein, and were paid at the dates respectively mentioned. Deponent further states that for some of these expenditures, such as traveling expenses, and some of the smaller items, he never had any bills, but did have for most of these expenditures, and that they are presented herewith in a package marked, "Bills in claim of A. H. Emery against the U. S. Government in Exhibit L.—Bill of sundries," each of said bills themselves bearing the indorsement, "Original—No. [ ] in Exhibit L, Claim of A. H. Emery," the brackets containing the numbers given to these bills in the statement; and that none of these expenses are shown or included in any other exhibit. O. C. Woolson, being duly sworn, deposes and says that he was employed by the abovementioned A. H. Emery as a draftsman and superintendent during several years of the time in which the said Emery was designing, constructing, and testing the abovementioned testing-machine; and the said Emery and the said Woolson, each separately and for themselves, depose and say that the books and accounts of the said Emery show all the expenditures mentioned in the inclosed statement, amounting to the said sum of $3,441.83. And said deponents further state, that the said statement is, for the purpose of identification, marked on the back, "Claim of A. H. Emery against the U. S. Government in Exhibit L.—Bill of sundries in cost of the government testing-machine," and is indorsed at the bottom on the inside, "Correct statement of sundry expenses incurred by A. H. Emery in connection with designing, constructing, and testing the testing-machine built by him for the United States Government," and that said indorsement is signed by the said Emery and the said Woolson. And the said Emery and the said Woolson, each of them, depose and say, that all the expenditures mentioned in the said statement were believed to be necessary to the proper design, construction, and testing of said machine, and in connection therewith, and that they were, as shown by said statement, of the following amounts, for the time herein shown, to wit:

During 1873 and 1874 to January 1, 1875	$157 72
From January 1, 1875, to April, 1875	129 18
From April 1, 1875, to July 1, 1875	171 12
From July 1, 1875, to October 1, 1875	373 98
From October 1, 1875, to December 31, 1875	386 12
From January 1, 1876, to April 1, 1876	241 35
From April 1, 1876, to July 1, 1876	260 10
From July 1, 1876, to October 1, 1876	332 76
From October 1, 1876, to January 1, 1877	186 49
From January 1, 1877, to April 1, 1877	315 60
From April 1, 1877, to July 1, 1877	350 26
From July 1, 1877, to October 1, 1877	115 29
From October 1, 1877, to December 31, 1877	30 22
From January 1, 1878, to April 1, 1878	89 51
From April 1, 1878, to January 1, 1879	240 14
From January 1, 1879, to February 15, 1879	61 99
Making in all the sum of	3,441 83

(Three thousand four hundred and forty-one dollars and eighty-three cents, exclusive of interest.)

A. H. EMERY.
O. C. WOOLSON.

Duly and severally sworn to by the subscribers, before me, March 22, 1880.

SEAL.]

HAROLD SMITH,
Notary Public, New York County.

M.—*Salary of J. E. Howard, assistant engineer.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY OF BOSTON, COUNTY OF SUFFOLK AND STATE OF MASSACHUSETTS, *ss:*

J. E. Howard, being duly sworn, says that he is a civil engineer, and that he was employed by A. H. Emery, of New York City, from August 16, 1875, to February 16, 1879, as an assistant engineer, while constructing, testing, and erecting the testing-machine built by said Emery for the United States Government, and that two years eleven and one-sixth months of this time he was employed at Chicopee, Mass., partly in the office and partly in the shop, making drawings and computations and doing other office work, also in superintending, aiding, and assisting in constructing, experimenting, testing, and other work in the shop, all of which said work, occupying said two years eleven and one-sixth months, was believed to be necessary and essential to the proper construction of the said testing-machine; and deponent further says that for said services he has been paid the following sums, and at the times herein given, to wit:

During September, October, November, and December, 1875, at various dates	$165 00
During January and February, 1876	90 00
During April and May, 1876	100 00
During July and August, 1876	112 00
During September and October, 1876	120 00
During November and December, 1876	115 00
During January and February, 1877	175 00
During March and April, 1877	160 00
During May and June, 1877	85 00
During July and August, 1877	195 00
During September and October, 1877	95 00
During November and December, 1877	177 00
During January and February, 1878	195 00
During March and April, 1878	120 00
During June, July, and August, 1878	271 00
During September and October, 1878	92 00
Making in all the sum of	2,267 00

Which is $900 per year for two years, and $467, or at the rate of $500 per year, for the eleven and one-sixth months for which there is also due and to be paid to him the additional sum of $372.22, making the salary for this time also $900 per year, which said sum of $372.22 will be due and payable when said Emery shall have been reimbursed by the government for the cost of the said testing-machine, making the total payments made and to be made together of the sum of $2,639.22.

JAMES E. HOWARD.

Subscribed and sworn to before me this 11th day of March, A. D. 1880.
[SEAL.]
GEORGE M. AMERIGE,
Notary Public.

N.—*Bills South Boston Iron Company.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY, COUNTY, AND STATE OF NEW YORK, *ss:*

William P. Hunt, being duly sworn, deposes and says that he is the treasurer of the South Boston Iron Company, a company duly organized by law in the city of Boston, Mass., and that during the years 1875 to 1879, inclusive, the said South Boston Iron Company was employed by A. H. Emery, of New York City, to construct some parts of the testing-machine which he built for the United States Government, and to furnish labor and materials therefor. And that in the prosecution of this work the said company did furnish various amounts of labor, materials, castings, &c., all of which were charged for at the rates and prices agreed upon, which rates and prices were just and equitable and believed to be necessary to the proper construction of said machine. Said deponent further says that bills of this work were presented the said Emery from time to time, and audited by him as correct, and were all settled by him on October 4, 1877, and March 18, 1879. Said deponent further states that the amount of these bills

were in the aggregate of the amount of $8,500.17 (eight thousand five hundred and $\frac{17}{100}$ dollars), which amount was paid as follows, to wit:

On October 4, 1877	$250 00
On February 7, 1878	7,256 00
On July 21, 1879	994 17
Making in all the sum of	8,500 17

Deponent further states that a correct copy of these bills, showing their items in detail with their settlements and payments indorsed thereon, is presented herewith, and that this said copy is indorsed at the bottom, "Correct copy of bills presented to A. H. Emery for labor, materials, &c., furnished on and for the testing-machine built by him for the United States Government and paid as above shown. Alexander Paul, bookkeeper, South Boston Iron Company, William P. Hunt, treasurer South Boston Iron Co.," and on the back thereof, "Claim of A. H. Emery against the U. S. Government in Exhibit N.—Bills South Boston Iron Co."

WM. P. HUNT.

Subscribed and sworn to before me this 13th day of February, A. D. 1880.
Witness my hand and official seal.

[SEAL.] MOSES M. ROBINSON,
Notary Public, New York County.

O.—*Bills Nashua Iron and Steel Company.*

In the matter of the claim of A. H. Emery against the United States Government.

CITY OF BOSTON, COUNTY OF SUFFOLK, AND STATE OF MASSACHUSETTS, *ss:*

M. A. Herrick, being duly sworn, deposes and says that he is the treasurer of the Nashua Iron and Steel Company, a company duly organized by law in Nashua, New Hampshire, and that during the years 1875 to 1879 the said Nashua Iron and Steel Company furnished for A. H. Emery, of New York City, various forgings and materials to be used for and in the construction of the testing-machine he, the said Emery, was building for the United States Government, and that for the said forgings, labor, and material so furnished, the said company presented bills to the said Emery as the work was done, from time to time, all of which were audited by him as correct; and said deponent further states that all these bills were at the rates agreed upon, and were just and reasonable, and that all the said material was believed to be necessary to the proper construction of the said testing-machine and its belongings. The said deponent further states that a correct copy of these bills has been presented to the said Emery, all in one voucher, dated Nashua, N. H., February 13, 1880, to go with this deposition, and that said copy shows the aggregate amount of all these bills to be of the sum of $5,188.45 (five thousand one hundred and eighty-eight and $\frac{45}{100}$ dollars), on which the following payments have been made, and at the times therein and herein stated, to wit:

On January 29, 1876	$335 90
On February 11, 1876	1,097 03
On February 26, 1876	368 38
On May 11, 1876	1,893 91
On July 26, 1876	949 16
On August 23, 1876	3 25
On February 6, 1887	12 60
Making in all the sum of	4,660 23
Leaving still due and unpaid, including interest to January 1, 1880, the sum of	528 22

Said deponent further states that said voucher is indorsed at the bottom, "The above is a correct copy of bills presented to A. H. Emery for material furnished for the construction of the testing-machine built by him for the United States Government. Horatio Adams, bookkeeper of Nashua Iron and Steel Co.; M. A. Herrick, treasurer of the Nashua Iron and Steel Co." And on the back thereof, "Claim of A. H. Emery against the U. S. Government, in Exhibit O.—Bills Nashua Iron and Steel Co."

M. A. HERRICK.

In presence of
GODFREY MORSE.

COMMONWEALTH OF MASSACHUSETTS, SUFFOLK, *ss:*

BOSTON, *February* 14, 1880.

There appeared before me the above-named M. A. Herrick, and made solemn oath that the statement above subscribed by him is true.

[SEAL.] GODFREY MORSE, *Notary Public.*

P.—*Bills of Ames Manufacturing Company.*

In the matter of the claim of A. H. Emery against the United States Government.

TOWN OF CHICOPEE,
County of Hampden, and State of Massachusetts, ss:

Luther White, being duly sworn, deposes and says, that he is the treasurer of the Ames Manufacturing Company, a company duly organized by law in Chicopee, Mass.; and Charles L. Pepper, being duly sworn, deposes and says, that he is the bookkeeper of the said Ames Manufacturing Company; and the said White and the said Pepper each for themselves, say that during the years 1875 to 1879, inclusively, the said Ames Manufacturing Company was employed by A. H. Emery, of New York City, to aid him in the construction of the testing-machine which he built for the United States Government, and that in the prosecution of this work the following bills were made by the said Ames Manufacturing Company and presented to the said Emery for payment, and audited by him as being correct; and that these bills were made and according to the terms agreed upon before the different parts of the work were severally commenced by the said Ames Manufacturing Company, and that all of the said bills are for labor and materials furnished as stated therein. The said deponents further say that the said bills referre to as "following bills" are 45 in number, and are each indorsed inside, "Correct copy. Luther White, Treas.," and on the backs thereof, "Claim of A H. Emery against the U. S. Government, in Exhibit P.—Bills Ames Mf. Co.," and are numbered on the back from Nos. 1 to 45, inclusively, with the month and year for which they were made also written thereon.

The said deponents further say that the following are the numbers, dates, and amounts of said bills, to wit:

Number 1. July 31, 1875	$973 96
Number 2. August 31, 1875	1,057 83
Number 3. September 30, 1875	2,074 70
Number 4. October 31, 1875	1,331 79
Number 5. November 30, 1875	3,463 85
Number 6. December 31, 1875	2,393 30
Number 7. January 31, 1876	1,865 01
Number 8. March 1, 1876	1,227 48
Number 9. March 31, 1876	1,510 19
Number 10. April 29, 1876	1,192 12
Number 11. June 1, 1876	1,416 33
Number 12. July 1, 1876	1,554 74
Number 13. July 31, 1876	1,115 84
Number 14. August 31, 1876	1,063 88
Number 15. September 30, 1876	1,213 99
Number 16. October 31, 1876	1,315 81
Number 17. November 30, 1876	1,999 34
Number 18. December 30, 1876	909 77
Number 19. January 31, 1877	792 80
Number 20. February 28, 1877	806 27
Number 21. March 31, 1877	824 20
Number 22. April 30, 1877	1,073 81
Number 23. May 31, 1877	1,129 17
Number 24. June 30, 1877	943 46
Number 25. July 31, 1877	675 65
Number 26. August 31, 1877	504 09
Number 27. September 29, 1877	379 29
Number 28. October 31, 1877	309 78
Number 29. November 30, 1877	335 01
Number 30. December, 1877	320 34
Number 31. January 31, 1878	479 14
Number 32. February 28, 1878	323 79
Number 33. March 31, 1878	227 74
Number 34. April 30, 1878	174 20
Number 35. June 1, 1878	137 44
Number 36. June 29, 1878	179 78
Number 37. July 31, 1878	166 18
Number 38. August, 1878	196 63
Number 39. September 30, 1878	88 75
Number 40. October 31, 1878	21 21
Number 41. November 30, 1878	15 00
Number 42. December 31, 1878	17 61
Number 43. January 31, 1879	15 00

Number 44. February, 1879	$15 00
Number 45. April 30, 1879	45 92
Making in all the sum of	37,877 19

(Thirty-seven thousand eight hundred and seventy-seven and $\frac{19}{100}$ dollars.)

The said deponents further say that all the labor and materials charged in these bills were charged at the rates agreed upon, and that such prices were just and reasonable, and that all the labor and materials therein charged were believed to be necessary to the proper construction and testing of said testing-machine.

The said deponents further testify that the said Emery has made the following payments on the above-mentioned bills to the said Ames Manufacturing Company, and at the dates here given, to wit:

On September 16, 1875	$2,930 00
On December 7, 1875	1,176 49
On January 24, 1876	3,500 00
On February 15, 1876	5,500 00
On July 25, 1876	1,500 00
On January 20, 1877	1,630 00
On March 31, 1877	6,738 47
On June 20, 1877	9,769 05
Making in all these payments the sum of	32,744 01

(Thirty-two thousand seven hundred and forty-four and $\frac{1}{100}$ dollars), besides which there is still due on the said bills the following sums, to wit:

On August 1, 1878	$4,718 06
On September 1, 1878, the bills of August and September, 1878	185 38
On May 1, 1879, the bills of October, November, and December, 1880, and January, February, and April of 1879	129 74
On which interest has accrued up to January 1, 1880, at 7 per cent., as follows: $467.87, $26, 63, and $6.04; in all	500 54
Leaving the amount due January 1, 1880	5,533 72

Which amount of five thousand five hundred and thirty-three dollars and seventy-two cents is still due with interest from January 1, 1880, at the rate of 7 per cent.

LUTHER WHITE.
CHAS. L. PEPPER.

Severally subscribed and sworn to before me this 11th day of February, A. D. 1880.

[SEAL.] LORAMUS E. HITCHCOCK,
Notary Public.

[Indorsements.]

EXECUTIVE MANSION,
March 26, 1880.

Calls attention to letter of president of Board for Testing Steel and Iron, recommending an appropriation to reimburse Mr. Emery for loss, allowance, and use of patent, &c., and incloses additional papers upon the subject.

Respectfully referred to the Secretary of War.

By direction of the President.

W. K. ROGERS,
Private Secretary.

[First indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, March 26, 1880.

Respectfully referred to Col. T. T. S. Laidley, president of the late Board on Steel and Iron, for remark.

1st. Mr. Emery now claiming compensation from the United States not only for the actual cost to him of the machine over and above the

contract price, but for the use of his patents, and for consequential damages caused by the free use of the machine to all persons, as given by Congress, &c.

2d. Is the amount of $200,000, if *now* paid by Congress, excessive or more than sufficient to compensate Mr. Emery for losses and allowance on the contract, and for his time and labor and use of patents and damage from the free use of machine, &c., for all or any of these?

3d. Colonel Laidley will submit any papers bearing on this case.

By order of the Chief of Ordnance.

S. C. LYFORD,
Major of Ordnance.

[Second indorsement.]

WATERTOWN ARSENAL, *March* 30, 1880.

Respectfully returned to the Chief of Ordnance.

The inclosed papers, which have been carefully examined by the undersigned, show that the testing-machine invented and constructed by Mr. A. H. Emery for the government has cost him much more than had been supposed in February, 1879, when, without going into an examination of books and papers, the cost was set down at $100,000. The undersigned thought, from a report made by the contractor in 1877, that the cost, when figured up, would be probably less.

The act of Congress, approved June 20, 1878, which directs that this machine shall be applied to the testing of materials for all persons who may desire to use it upon the payment of the actual cost of making the tests, which action virtually destroys the business of the inventor of building testing-machines, in that no one will purchase a machine when he can have the work of testing done by the government at less cost than he could do it himself if a machine were furnished to him free of charge, gives the inventor a strong claim for greatly-increased damages, and causes the undersigned to modify and increase the sum which, in his opinion, the government could well afford to pay for this machine and the losses its action has inflicted.

When the contractor undertook to build this machine he confidently expected that it would be completed within six months, whereas nearly five years were consumed in its perfection. This is nearly one-third of the entire life of his valuable patents, and involves a loss to him, without any fault of his, which, though doubtless great, it would be difficult accurately to estimate.

It rarely happens in the development of any new invention that the first construction does more than show what may be accomplished in succeeding efforts. In the present instance, however, so thoroughly were all the details digested, and such frequent changes made in drawings before they passed into the hands of the workmen, that this first machine forms a marked exception to the general rule, and is more perfect in all its parts than could have been reasonably expected under the terms of the contract. This result, however, has not been accomplished without long and laborious study, and a corresponding increase of expense to the contractor. Since the government is thereby the gainer, it can well afford to offer a substantial compensation therefor. Had the contractor failed to raise the necessary funds to complete the machine in accordance with his high standard of excellence, the undersigned, though conversant with the testing-machines used by the principal nations, knows of none which could have been procured combining all of the desired qualities to the extent of that the United States now possesses. No one who has witnessed the facility of its operation, and understood the principles

upon which it is based, has failed to appreciate and be impressed with the delicacy and accuracy of its determinations. This is a matter of no small importance, since it is to form the standard throughout the country for measuring such strains as are ordinarily determined by testing-machines.

Its reputation is not confined to this continent, but wherever a knowledge of its capabilities has extended it reflects credit upon the American name. Under these circumstances the government can well afford to be liberal with the contractor, and make a fair compensation to him for his great creative power and unremitting labor during the five best years of his life. The amount of $200,000, if now paid by Congress, would not, in the judgment of the undersigned, be excessive, or more than sufficient to pay the contractor a fair equivalent for his unusual devotion to the interests of the government, the work performed by him, and the losses sustained during the time that he has given up his undivided energies to this undertaking.

T. T. S. LAIDLEY,
Colonel of Ordnance, Commanding.

[Third indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 13, 1880.

Respectfully returned to the Secretary of War, inviting special attention to the indorsement of Colonel Laidley, president of the late Board on Steel and Iron, and the views of a majority of the members. The other members of the board, being absent or sick, have not been consulted.

As stated in my indorsement of February 18, 1879, herewith, I know nothing of the merits but what is made to appear by these papers. The inventor has produced a testing-machine believed to be the most reliable and perfect in the world, and reflecting the greatest credit on the inventive genius and mechanical skill of one of our citizens. No one can question the fact that in the laudable desire to do his whole duty to the country, and give it the master-piece of his designing and constructive faculty, he has seriously involved himself pecuniarily, and has not received any compensation for his very arduous labors. In the construction of this machine he has expended large sums over and above the amount paid him under the contract.

It is a case that appeals strongly to our sympathies, and to our sense of justice equitably rendered. In this view I respectfully recommend this matter to favorable consideration.

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

[Copy of second indorsement.]

WATERTOWN ARSENAL, *March* 30, 1880.

Respectfully returned to the Chief of Ordnance.

The inclosed papers, which have been carefully examined by the undersigned, show that the testing-machine invented and constructed by Mr. A. H. Emery for the government has cost him much more than had been supposed in February, 1879, when, without going into an examination of books and papers, the cost was set down at $100,000. The undersigned thought, from a report made by the contractor in 1877, that the cost when figured up would be probably less.

The act of Congress approved June 20, 1878, which directs that this machine shall be applied to the testing of materials for all persons who may desire to use it, upon the payment of the actual cost of making the tests, which action virtually destroys the business of the inventor or building testing-machines, in that no one will purchase a machine when he can have the work of testing done by the government at less cost than he could do it himself if a machine were furnished to him free of charge, gives the inventor a strong claim for greatly increased damages, and causes the undersigned to modify and increase the sum which, in his opinion, the government could well afford to pay for this machine. and losses its action has inflicted. When the contractor undertook to build this machine he confidently expected that it would be completed within six months, whereas nearly five years were consumed in its perfection. This is nearly one-third of the entire life of his valuable patents, and involves a loss to him without any fault of his, which, though doubtless great, it would be difficult accurately to estimate.

It rarely happens in the development of any new invention that the first construction does more than show what may be accomplished in succeeding efforts. In the present instance, however, so thoroughly were all the details digested, and such frequent changes made in drawings before they passed into the hands of the workman, that this first machine forms a marked exception to the general rule, and is more perfect in all its parts than could have been reasonably expected under the terms of the contract. This result, however, has not been accomplished without long and laborious study, and a corresponding increase of expense to the contractor. Since the government is thereby the gainer, it can well afford to offer a substantial compensation therefor. Had the contractor failed to raise the necessary funds to complete the machine in accordance with his high standard of excellence, the undersigned, though conversant with the testing-machines used by the principal nations, knows of none which could have been procured combining all of the desired qualities to the extent of that the United States now possesses. No one who has witnessed the facility of its operation, and understood the principles upon which it is based, has failed to appreciate and be impressed with the delicacy and accuracy of its determinations. This is a matter of no small importance, since it is to form the standard throughout the country for measuring such strains as are ordinarily determined by testing-machines. Its reputation is not confined to this continent, but wherever a knowledge of its capabilities has extended it reflects credit upon the American name.

Under these circumstances the government can well afford to be liberal with the contractor and make a fair compensation to him for his great creative power and unremitting labor during the five best years of his life.

The amount of $200,000, if now paid by Congress, would not, in the judgment of the undersigned, be excessive, or more than sufficient to pay the contractor a fair equivalent for his unusual devotion to the interests of the government, the work performed by him, and the losses sustained during the time that he has given up his undivided energies to this undertaking.

T. T. S. LAIDLEY,
Colonel of Ordnance, Commanding.

We, the undersigned, formerly members of the United States Board for Testing Iron and Steel, had supposed that the testing-machine had cost the sum stated by the contractor, and no one who has seen the

machine will be surprised to learn that it has really cost a larger sum, as ascertained by the contractor in making up his accounts. We fully agree with Colonel Laidley in all his remarks with regard to the quality and value of the machine and the services rendered by Mr. Emery in designing and constructing it. And we think that he is justly entitled to compensation for its cost as shown and the allowance he asks as a contractor, and that he should be paid for his time and the use of his patents in the construction of said machine. We also think that Congress and the country can well afford to pay him the sum of $200,000 to settle his claim, and should any part of the cost of the machine or other part of his claim be for any cause disallowed, we would still recommend that a sum not less than $200,000 be paid to him in recognition of his genius, fidelity, and services; and if not paid now we would recommend a larger sum hereafter as including compensation for delay.

WM. SOOY SMITH, *C. E.*
A. L. HOLLEY.
Q. A. GILLMORE,
Lieut. Col. Eng., Bvt. Maj. Gen.

[House Report No. 1584, Forty-sixth Congress, second session.]

ALBERT H. EMERY.

Mr. BOWMAN, from the Committee on Claims, submitted the following report [to accompany bill H. R. 6373]:

The Committee on Claims, to whom was referred the bill (H. R. 5990) *for the relief of A. H. Emery, have considered the same, and respectfully report:*

By an act approved March 3, 1873, Congress appropriated $25,000 for improved machinery for testing American iron and steel (17 Stat. at Large, p. 547). Under this appropriation the Ordnance Department ordered of A. H. Emery, civil engineer, of New York, a testing machine to be designed and built by him, and erected at the Watertown Arsenal, Mass., as will more fully appear from the memorial of the claimant accompanying the message of the President to the House on the 16th of April, 1880. (See Ex. Doc. No. 74.)

2. The papers contained in said Ex. Doc. No. 74 show that under this order the claimant diligently and continuously proceeded with the designing and construction of the said machine. During the progress of this work Congress passed an act, approved March 3, 1875 (18 Stat., p. 399), appropriating $50,000 for "experiments in testing iron and steel, *including the cost of any machine built for the purpose*," and the above appropriation of $25,000 made by the act of March 3, 1873, was made available as a "further sum" for the purpose of building such machine. (See section 4.) This section also provided that the President should appoint a board consisting of one engineer and one ordnance officer of the army, one line officer and one engineer of the navy, and three civilian experts, for the purpose of making tests of the strength and value of all kinds of iron and steel and other metals, and for the building of a *suitable machine* for establishing such tests. The President appointed on this board General Q. A. Gillmore, Engineers, United States Army; Col. T. T. S. Laidley, of the Ordnance Bureau; Commander L. A.

Beardslee, United States Navy; David Smith, Chief Engineer, United States Navy; General William Sooy Smith, civilian, civil engineer; A. L. Holley, civilian, civil engineer; R. H. Thurston, civilian, civil engineer.

3. Under this act, which placed the board above named in the position formerly held by the Ordnance Office as regards this machine, the said board made a new contract with the claimant after he had been at work upwards of a year and a half under his original contract. By the said new contract the board required certain additional apparatus, which increased the weight of the machine about ten per cent., and for this additional apparatus added $6,500 to the original contract price, thus changing the price to be paid from $25,000 to $31,500.

4. Under this contract the work was continued unremittingly until the 8th of February, 1879, when the machine was completed and accepted.

5. From statements of the claimant, which there is no reason to doubt, it appears that his inventions embodied in this machine were for the most part matured prior to the date when the machine was ordered, to wit, the 24th of December, 1873. The papers show that at that time no design of the machine had been made, and that the claimant pursued with untiring industry and skill the designing, constructing, testing, and perfecting of this machine, which proved to be an unexpectedly difficult and expensive task. Colonel Laidley, president of the board above alluded to, says in regard to this, in a letter addressed to the President of the United States, dated February 10, 1879, two days after the machine had been accepted by the board, as follows:

> In the plans designed by Mr. Emery he adopted new principles, in the working out of which he met, as is always the case under such circumstances, with great and unlooked-for difficulty. In overcoming these difficulties, Mr. Emery has spent more money than he has received for the entire machine, to say nothing of his other expenses, time, labor, &c. He has throughout, in the performance of his part of the contract, shown a greater desire to make the machine perfect in all its details than to complete the work and obtain his money. The result of this unusual devotion is, that the United States has at this time a more perfect machine than was called for by the terms of the contract.

And in the same report to the President, in speaking of the character of the machine, he uses the following language:

> This machine combines the qualities of power and delicacy to an extent hitherto unknown, and is equally adapted to the testing of the ultimate strength of an iron bar 30 feet in length and 5 inches in diameter and of a piece of wire of the finest size drawn, 1 inch long, and is capable of giving the exact strain of rupture of each. This is more than can be said of any other machine now in existence; in fact its capabilities and the ease with which the greatest strains are applied are such as to pass even the bounds of belief of those who have not witnessed its operation.

6. At the time of the acceptance of the machine, and prior to this report of the president of the board to the President, attention was called to the fact that the cost of the machine was vastly in excess of the contract price. The claimant, without examination of his accounts, stated that the cost was at least $100,000. One member of the board then recommended the payment of not less than $45,000 additional compensation, while five other members of the board recommended the payment of $70,000 additional, which latter amount, added to the contract price, would only have reimbursed him for actual outlay as then estimated without any compensation for his own time and skill or for the use of his inventions.

7. The said members of the board, while recommending the payment of $70,000 additional compensation, state that, as the board did not intend the machine should be made without a reasonable profit, they would, had the contractor asked it, have recommended that he be paid for his time as well as disbursements.

8. The above-referred to report and letters of recommendation were made the subject of Senate Ex. Doc. No. 68, parts 1 and 2, 45th Cong., 3d sess., which reached Congress so near the close of the session that no action was taken thereon.

9. Since that time the claimant has accurately ascertained the cost of the machine, and has furnished a detailed statement thereof, certified by affidavits of himself and of the parties who furnished the labor and materials. His memorial setting forth the history of the case, with proofs of the cost of the machine, were inclosed in his letter to the President dated March 27, 1880, which papers, with the indorsements thereon, were made the subject of a special message of the President to the House, dated the 16th of April, 1880, and found in Ex. Doc. No. 74, present session.

10. The documents further show that before the machine was designed it was expected to contain, when completed, about 80,000 pounds of finished metal work, whereas it really contains about 170,000 pounds, and more than twice this quantity (or upwards of four times the amount it was originally expected to contain) was put into the furnaces and forges to produce it.

11. It further appears from the documents on file that in order to produce such a machine as the government and the board required, many parts, though constructed with great care, had to be made over and over again; and without entering into details as to changes, enlargements, new inventions and devices that were made and used to perfect the machine, it is sufficient to say that the proofs show the actual cost of the machine to have been upwards of $129,000, for which he has received $31,500, exclusive of interest. These proofs as to cost and other details were submitted to Colonel Laidley, president of the board, and carefully examined by him, and will be found in detail in Ex. Doc. No. 74, above cited.

12. This cost does not include any allowance for the value of the invention used in the machine, nor is there embraced in it anything for profits; both which items should be considered in fixing the amount to be paid, for no one could wish the government to use this machine, even at cost, without compensation to him for his inventions and his time, nor that he should assume the heavy expense and risk involved without a fair profit.

13. The above would have been a reasonable basis of settlement but for the fact that in the sundry civil bill, approved June 20, 1878, Congress enacted—

> That the Secretary of War is hereby authorized to cause the machine built for testing iron and steel to be set up and applied to the testing of iron and steel for all persons who may desire to use it, upon the payment of a suitable fee for each test; the table of fees to be approved by the Secretary of War, and to be so adjusted from time to time as to defray the actual cost of the tests as near as may be; and, in order to make the final payment on contract for the construction of this machine, the sum of six thousand two hundred and ninety-nine dollars and forty-eight cents of the unexpended balance now remaining on the books of the Treasury of the appropriation for this purpose is hereby reappropriated and made available therefor.

This act, passed while the claimant was setting up his machine, virtually deprived him of the proper use of his inventions, most of which he had matured before the machine was ordered for the use of the government, and in the development of which he had spent, as has been shown, more than five years of time. The use of the machine by the government for the benefit of the public for merely nominal fees manifestly deprives the claimant of any considerable market for the sale of these machines.

14. It is not the government only which is interested in testing the strength of materials, but manufacturers, constructing engineers, builders, and in general the whole public, who are constantly exposed to peril from the treachery of metallic structures of uncertain strength.

15. A letter from members of the board, dated February 17, 1879 (see Senate Ex. Doc. No. 68, Forty-fifth Congress, 3d session), says:

He has spent every dollar he asks and more, we believe, on this machine, and the government has got the value of the expenditure tenfold as compared with the value of any other known testing-machine.

16. The Secretary of War, in his letter to the President, informs him that this is the most perfect testing-machine in the world, and that Colonel Laidley and other members of the board recommend the payment of $200,000 to the contractor.

17. The following are the communications of the President and Secretary of War on the subject embraced in Ex. Doc. No. 74, before referred to:

EXECUTIVE MANSION,
Washington, D. C., April 16, 1880.

To the House of Representatives:

The Board for Testing Iron, Steel, and other metals, appointed under the authority of "An act making appropriations for sundry civil expenses of the government for the fiscal year ending June 30, 1876, and for other purposes," contracted with Mr. A. H. Emery, of New York, for a testing-machine, to be paid for out of the appropriation made for the purpose. That machine has been completed and accepted, and is now in position at the Watertown Arsenal, Massachusetts. It is spoken of by the members composing the late board as the most perfect and reliable machine in the world, embodying new mechanical principles and combinations not heretofore used in any other constructions.

In designing, perfecting, and making this machine the contractor has expended large sums of money over and above the contract price, besides giving years of labor for which he has received no compensation. He now appeals to Congress for relief, and the papers herewith exhibit a case that calls for Congressional action. It is respectfully submitted to the House of Representatives, recommending speedy and favorable consideration.

R. B. HAYES.

WAR DEPARTMENT,
Washington City, April 14, 1880.

SIR: I have the honor to return the papers in the claim of Mr. A. H. Emery.

These papers have been referred to the Chief of Ordnance, and your attention is invited to his indorsement, and to that of Colonel Laidley, president of the late board on steel and iron, as well as to the views of some of the members of the board.

This is a case that calls for Congressional action. These papers show that it is one deserving favorable consideration.

The country is now in possession of the most perfect testing-machine in the world. The use of metals in all kinds of constructions, both private and public, demands so accurate a knowledge of their qualities as can only be determined by just such a machine as this, and its determinations will be of the greatest value to one of the most extensive industries in which our people are engaged.

It appears to me that liberal action on the part of Congress towards one of our citizens who has lost so much in faithfully carrying out his contract would be but proper and equitable.

Colonel Laidley and other members of the board who are thoroughly cognizant of all the facts, name $200,000 as not excessive, "or more than sufficient to pay the contractor for his unusual devotion to the interests of the government."

I respectfully recommend reference of these papers to Congress with request for speedy and favorable action.

Very respectfully, your obedient servant,

ALEX. RAMSEY,
Secretary of War.

The PRESIDENT.

18. Accompanying this executive document will be found the letter of the claimant to the President of the United States, inclosing his memorial and exhibits, showing the cost of the testing-machine, which re-

ceived the following indorsements in which the Chief of Ordnance and the president and other members of the board recommend the payment of this sum:

[Indorsements.]

EXECUTIVE MANSION,
March 26, 1880.

Calls attention to letter of president of Board for Testing Steel and Iron, recommending an appropriation to reimburse Mr. Emery for loss, allowance, and use of patent, &c., and incloses additional papers upon the subject.

Respectfully referred to the Secretary of War.

By direction of the President.

W. K. ROGERS,
Private Secretary.

[First indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, March 26, 1880.

Respectfully referred to Col. T. T. S. Laidley, president of the late Board on Steel and Iron, for remark.

1st. Mr. Emery now claiming compensation from the United States not only for the actual cost to him of the machine over and above the contract price, but for the use of his patents, and for consequential damages caused by the free use of the machine to all persons, as given by Congress, &c.

2d. Is the amount of $200,000, if *now* paid by Congress, excessive or more than sufficient to compensate Mr. Emery for losses and allowance on the contract, and for his time and labor and use of patents and damage from the free use of machine, &c., for all or any of these?

3d. Colonel Laidley will submit any papers bearing on this case.

By order of the Chief of Ordnance.

S. C. LYFORD, *Major of Ordnance.*

[Second indorsement.]

WATERTOWN ARSENAL, *March* 30, 1880.

Respectfully returned to the Chief of Ordnance.

The inclosed papers, which have been carefully examined by the undersigned, show that the testing-machine invented and constructed by Mr. A. H. Emery for the government has cost him much more than had been supposed in February, 1879, when, without going into an examination of books and papers, the cost was set down at $100,000. The undersigned thought, from a report made by the contractor in 1877, that the cost, when figured up, would be probably less.

The act of Congress, approved June 20, 1878, which directs that this machine shall be applied to the testing of materials for all persons who may desire to use it upon the payment of the actual cost of making the tests, which action virtually destroys the business of the inventor of building testing-machines, in that no one will purchase a machine when he can have the work of testing done by the government at less cost than he could do it himself if a machine were furnished to him free of charge, gives the inventor a strong claim for greatly-increased damages, and causes the undersigned to modify and increase the sum which, in his opinion, the government could well afford to pay for this machine and the losses its action has inflicted.

When the contractor undertook to build this machine he confidently expected that it would be completed within six months, whereas nearly five years were consumed in its perfection. This is nearly one-third of the entire life of his valuable patents, and involves a loss to him, without any fault of his, which, though doubtless great, it would be difficult accurately to estimate.

It rarely happens in the development of any new invention that the first construction does more than show what may be accomplished in succeeding efforts. In the present instance, however, so thoroughly were all the details digested, and such frequent changes made in drawings before they passed into the hands of the workman, that this first machine forms a marked exception to the general rule, and is more perfect in all its parts than could have been reasonably expected under the terms of the contract. This result, however, has not been accomplished without long and laborious study, and a corresponding increase of expense to the contractor. Since the government is thereby the gainer, it can well afford to offer a substantial compensation therefor. Had the contractor failed to raise the necessary funds to complete the machine in accordance with his high standard of excellence, the undersigned, though conversant with the testing-machines used by the principal nations, knows of none which could have been procured combining all of the desired qualities to the extent of that the United States now possesses. No one who has witnessed the facility of its operation,

and understood the principles upon which it is based, has failed to appreciate and be impressed with the delicacy and accuracy of its determinations. This is a matter of no small importance, since it is to form the standard throughout the country for measuring such strains as are ordinarily determined by testing-machines. Its reputation is not confined to this continent, but wherever a knowledge of its capabilities has extended it reflects credit upon the American name.

Under these circumstances the government can well afford to be liberal with the contractor and make a fair compensation to him for his great creative power and unremitting labor during the five best years of his life.

The amount of $200,000, if now paid by Congress, would not, in the judgment of the undersigned, be excessive, or more than sufficient to pay the contractor a fair equivalent for his unusual devotion to the interests of the government, the work performed by him, and the losses sustained during the time that he has given up his undivided energies to this undertaking.

T. T. S. LAIDLEY,
Colonel of Ordnance, Commanding.

We, the undersigned, formerly members of the United States Board for Testing Iron and Steel, had supposed that the testing-machine had cost the sum stated by the contractor, and no one who has seen the machine will be surprised to learn that it has really cost a larger sum, as ascertained by the contractor in making up his accounts. We fully agree with Colonel Laidley in all his remarks with regard to the quality and value of the machine and the services rendered by Mr. Emery in designing and constructing it. And we think that he is justly entitled to compensation for its cost as shown and the allowance he asks as a contractor, and that he should be paid for his time and the use of his patents in the construction of said machine. We also think that Congress and the country can well afford to pay him the sum of $200,000 to settle his claim, and should any part of the cost of the machine or other part of hi claim be for any cause disallowed, we would still recommend that a sum not less than $200,000 be paid him in recognition of his genius, fidelity, and services; and if not paid now we would recommend a larger sum hereafter as including compensation for delay.

WM. SOOY SMITH, *C. E.*
A. L. HOLLEY.
Q. A. GILLMORE,
Lieut. Col. Eng., Bvt. Maj. Gen.

[3d indorsement.]

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, April 13, 1880.

Respectfully returned to the Secretary of War, inviting special attention to the indorsement of Colonel Laidley, president of the late Board on Steel and Iron, and the views of a majority of the members. The other members of the board, being absent or sick, have not been consulted.

As stated in my indorsement of February 18, 1879, herewith, I know nothing of the merits but what is made to appear by these papers. The inventor has produced a testing-machine believed to be the most reliable and perfect in the world, and reflecting the greatest credit on the inventive genius and mechanical skill of one of our citizens. No one can question the fact that in the laudable desire to do his whole duty to the country, and give it the master-piece of his designing and constructive faculty, he has seriously involved himself pecuniarily, and has not received any compensation for his very arduous labors. In the construction of this machine he has expended large sums over and above the amount paid him under the contract.

It is a case that appeals strongly to our sympathies, and to our sense of justice equitably rendered. In this view I respectfully recommend this matter to favorable consideration.

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

20. The documents before us show that the claimant has not only been waiting for the money equitably due him since the time when the machine was accepted, but that a large part of the disbursements now to be refunded were made during the period from 1873 to 1879; and it would have been but reasonable, in a work of this magnitude, that payments should have been made by the government from time to time as expenses occurred. It will be seen that the President, Secretary of War, Chief of Ordnance, and president and members of the board all recommend speedy and favorable consideration.

21. Your committee recommend an appropriation of $200,000, as provided for in House bill No. 5990.

22. Legislation in reference to this machine may be found in the regular appropriation bills (*vide* Army bill, approved March 3, 1873; sundry civil bill, approved March 3, 1875; sundry civil bill, approved June 20, 1878; Army bill, approved May 4, 1880, appropriating money for the use of this machine).

Your committee therefore report the accompanying bill as a new draft of the one committed to your committee, and recommend that the same do pass. (*Vide* H. R. 6373.)

APPENDIX 18.

THE MILITIA.

[House Report No. 763, 46th Congress, 2d Session.]

Mr. SCALES, from the Committee on the Militia, submitted the following report (to accompany bill H. R. 5638):

The Committee on the Militia, to whom have been referred the bills (H. R. 992, H. R. 4889, and H. R. 4979) "to reorganize and discipline the militia of the United States," respectfully report:

That no material change has been made in the militia law since its original enactment in 1792. The provisions of the law have become obsolete and impracticable, and for many years there has been no pretense of regarding them or attempt to enforce them. Believing, therefore, that there can be no dissent to the necessity of some action, the committee have endeavored to frame a bill which, without changing the nature of the long-established relations between the general government and the militia of the States, might replace provisions that have become obsolete or that experience has proven impracticable by others that would make the militia an efficient and important factor in the economy of national defense. In this view the committee report the accompanying bill as a substitute for the several bills referred to them and recommend its passage.

The committee feel that it should be sufficient for them to submit this bill without further comment than was made on the subject by Washington, when he said to Congress that "it is unnecessary to offer arguments or recommendations of a measure on which the honor, safety, and well-being of our country so evidently and so essentially depend." Nevertheless, as the subject is one that has occupied the attention of Congress since the formation of our government, we are constrained to add a brief review of the questions involved, in the hope that it may assist in their intelligent consideration.

The purpose and opinion of the founders of our government is unequivocally expressed in the second amendment to the Constitution, which declares, "A well-regulated militia being necessary to the security of a free State." The unvaried agreement of all subsequent writers and statesmen with this assertion might well cause us to view with some alarm the fact that all attempts to secure an efficient militia have hitherto signally failed. While all agree that the perpetuity of a republican form of government depends on maintaining a well-regulated militia, the fact has been demonstrated that under no other form of government is it so difficult, owing to the indisposition of the people to submit to the enforcement of military duty in time of peace.

Washington, in his annual message to Congress in 1794, said: "The devising and establishing of a well-regulated militia would be a genuine source of legislative honor, and a perfect title to public gratitude." The wisdom of this assertion has been proven by the subsequent failure of all attempts at legislation. Nevertheless your committee are convinced that the solution of the difficulties is now easy, not through any supe-

rior wisdom of our own, but because time and experience have solved the difficulties for us. This solution we conceive to be to substitute a volunteer militia in place of enforced militia duty, believing that our population has reached such a number that the volunteer militia of the States will be sufficiently large and efficient for all the purposes for which militia can or ever should be used.

The committee, deeming that it may be interesting and perhaps aid in considering the propositions submitted, preface their own recommendations with the following brief outline of the

HISTORY OF THE MILITIA LAW:

No subject, unless it be that of finance, has so long and so often engaged the attention of Congress as that of the militia, and on none have more able and exhaustive reports been written by those whose slightest utterances we have been taught to honor and respect. The records of Congress are filled with messages from Presidents, reports of executive officers, reports of committees of both houses of Congress, and with plans and bills for the improvement and organization of the militia, to attempt even a brief outline of which would far exceed the proper limits of this report. We cannot, therefore, do more than give a brief outline of the most salient features in the history of the subject.

On July 18, 1775, the Continental Congress passed a series of resolutions recommending "to the inhabitants of all the United English Colonies in North America that all able-bodied effective men between sixteen and fifty years of age in each colony immediately form themselves into regular companies of militia." One of these resolutions is particularly suggestive, as it contains the germ of the volunteer system which has now grown to such proportions that we have been led to recommend its recognition, and is as follows:

> That one-fourth part of the militia in every colony be selected for minute men, of such persons as are willing to enter into the necessary service, * * * and as these minute men may eventually be called to action before the whole body of the militia are sufficiently trained, it is recommended that a more particular and diligent attention be paid to their instruction in military discipline.

On the formation of the Federal Government one of the earliest acts of the first House of Representatives, in 1789, was the appointment of a committee to prepare a bill to organize the militia. The session adjourned before the committee made a report, but at the following session, in 1790, General Knox, Secretary of War, submitted his celebrated plan for organizing the militia, accompanying it by a letter of transmittal which is remarkable for its terse, striking, and strong arguments. His plan, in brief, was that every boy on arriving at the age of eighteen years should be enrolled in the cadet corps of militia and be obliged to serve in camp of instruction thirty days in each of first two years and ten days the third year, and that no person arriving at the age of twenty-one years should be entitled to exercise the rights of a citizen unless he could produce his certificate of having so served; all citizens between twenty-one and forty-five years of age were to be enrolled in the main corps of militia and be obliged to drill four days in each year; and between forty-five and sixty years of age to be enrolled in the reserve corps, which should be assembled twice in each year for inspection of arms. Under his plan the general government was to furnish uniform, arms, equipments, and bear all the expenses of the camps of instruction.

The features of General Knox's plan were embodied in a bill by a committee of the House of Representatives, and the subject was discussed

through the two succeeding sessions until all of its original features were changed or modified, and the act of May 8, 1792, finally agreed upon and enacted. As this is the law still in force, we reserve a detailed explanation of its provisions, and simply state here that its main feature is that every citizen between eighteen and forty-five years of age shall be enrolled in the militia and shall arm and equip himself at his individual expense. This law was found to be so crude and inadequate that it became the subject of criticism immediately after its passage, and of efforts to amend it which have continued to the present time. As well expressed by Washington, after the attempt was made to put it in practical operation, it "exhibited such striking defects, as could not have been supplied but by the zeal of our citizens"; and in his annual messages to each succeeding session of Congress, during his two terms of office, he urged that the evident defects of the law be remedied.

In the session succeeding the enactment of the law an effort was made to repeal the provision requiring every citizen to arm himself. In the next following session, in 1794, a bill was reported by a committee of the House of Representatives to organize a "*select corps*" of militia, to be armed and equipped by the general government, and paid for service in annual camps of instruction. Different propositions, having in view these two changes in the militia system, were discussed in successive sessions until 1798, when the threatening condition of our relations with France culminated in the formation of a provisional army and other warlike preparations that temporarily suspended consideration of the militia system.

Our troubles with France having been amicably settled, the militia question again assumed prominence, and Jefferson, in his annual messages to Congress, importuned them to take some action. It was chiefly through his earnest efforts that the law of April 23, 1808 (section 1661 Revised Statutes), was passed, making a permanent appropriation of $200,000 a year to provide arms and equipments for the militia. Somewhat curiously, however, the requirement of the old law that every citizen should arm and equip himself was not repealed, and still remains the statute.

As the country was rapidly increasing in population the uselessness of requiring active military duty from the whole body of citizens became more apparent, and was felt to be an unnecessary burden. Jefferson, in his annual message in 1805, recommended that the militia be classified according to ages, and thought that those from eighteen to twenty-six years of age would form a sufficiently large body to be subjected to any duty in time of peace. This proposition was taken up by Congress, and in various forms was the subject of debate in successive sessions, until the war of 1812 put an end to the discussion without any result having been reached.

Madison was almost as urgent in his appeals to Congress to amend the militia law as Jefferson had been. In his annual message in 1810 he advanced a new proposition in the suggestion that the commissioned and non-commissioned officers of the militia should be assembled in annual camps of instruction at the expense of the general government; and in his last annual message, in 1816, he earnestly recommended a reorganization of the militia, and classifying them according to age.

Prompted by the recommendations of Madison, the Fourteenth Congress, in 1816, directed the Secretary of War to prepare and report a plan for the organization of the militia. Secretary of War Graham reported to the following session, recommending that the militia be divided into three classes according to age, and that the two younger classes be

required to assemble annually in camps of instruction and be armed, equipped, and subsisted at the expense of the general government. This report was referred to a committee of which General Harrison (then a Representative from Ohio) was chairman. Harrison took a deep interest in the subject, and presented a careful report. He deemed it essential that the whole body of the people should be instructed in military matters, and for this purpose recommended that military instruction be made a branch of education in every school in the country. Believing that it would entail too great an expenditure of time and money to subject the whole enrolled militia to drill and military training, he revived the propositions first made by President Madison, and recommended that the officers and sergeants be assembled annually in camps of instruction, be paid for their time, and be thoroughly drilled and instructed at the expense of the general government, which he estimated would amount to about one and a half million dollars a year. Harrison continued the agitation of the subject while he remained in Congress, and made reports in 1818 and 1819 urging action.

Various bills and propositions were introduced and discussed from 1819 to 1825, most of them, however, agreeing in classifying the militia so that only a small portion of it should be subject to any duty in time of peace, and that this portion should be maintained at the expense of the general government.

In 1825 Secretary of War Barbour addressed a circular letter to the governors of all the States and to many citizens most prominent in military and civil life, setting forth that it had long been apparent that some change in the militia law was necessary, and asking their views on the subject. He then convened a board composed of some of the most distinguished officers of the Army and Militia for the purpose of considering the question, and submitted to them the voluminous correspondence that had resulted from his circular letter. It is worthy of note that the president of this board was Winfield Scott, then a major-general in the Army, and that Zachary Taylor, then a lieutenant-colonel of artillery, was one of the members. The militia were represented on the board by General Cadwalader of Pennsylvania, General Sumner of Massachusetts, and General Daniel of North Carolina.

The report of this board (S. Docs., second session Nineteenth Congress, vol. 1), together with all the papers and correspondence connected with it, was transmitted to Congress by the President. The board reported that they considered the primary defect of the militia law to be in the excess of numbers which it held to service. They recommended that a select corps of militia be formed, to consist in each State of one brigade for every Congressional Representative, and that the officers of this select militia be assembled in camps of instruction ten days in each year, and be paid by the general government for their time and traveling expenses. They also recommended that the office of adjutant-general of militia be created, and that, on the application of State executives, the United States should furnish officers to instruct the annual camps.

From 1826 to 1835 the unanimity of opinion as to the absolute necessity of some change in the militia law was only equaled by the diversity of opinion as to what that change be, and resulted in unproductive discussion of numerous bills and propositions that were submitted.

In 1835 President Jackson, in his annual message, urged Congress, in his usual forcible style, to give their attention to the subject, and among other things recommended that volunteer organizations be encouraged and inducements held out for their formation. The Secretary of War (General Cass), in his annual report, gave his views on the subject, and

represented the necessity of some legislation. Urgent effort was made in Congress to secure agreement to some plan, but without success.

In 1840 Secretary of War Poinsett submitted a plan to Congress. Apparently despairing of securing agreement to any plan that simply changed and perpetuated the existing system, he proposed a radical reform that stretched the constitutional powers of the general government to such an extent as to cause opposition to it on that ground. His plan was to divide the militia into three classes—the active, reserve, and mass. The active militia to consist of 100,000 men, apportioned to the respective States, and each State to be required to keep its quota filled at all times, either by voluntary enlistment or draft. One fourth of the active militia to go out of service annually and be enrolled in the reserve corps. The mass of the militia not to be subject to any duty in time of peace. He proposed that Congress should by law authorize the President to order the active militia into the service and pay of the United States for thirty days in each year for the purpose of placing them in camps of instruction.

This appears to have been the last decided attempt to save the decaying system from dissolution, with the exception of an effort in 1846, when a bill was reported to remedy the excess of number of the militia by limiting the enrollment in time of peace to those between twenty-one and thirty years of age, who should be formed into a legion of active militia in each State, the officers of which should serve annually in camps of instruction at the expense of the general government.

The militia system, by this time, was virtually dead; during the many years devoted to debating a remedy for its defects it had gradually sunk, until it no longer existed except on the statute-book. In the mean time, in all the States, by a process of "natural selection," there had sprung up volunteer organizations of militia, and the States, by fostering and encouraging them, had supplied the deficiencies of the general law. These volunteer organizations made possible and gave efficiency to that splendid body of volunteers whose soldierly qualities and deeds of valor in the Mexican war gave such renown to our arms. After that war still greater interest was manifested in the volunteer militia; the States devoted to them the meager supply of arms and equipments obtained annually from the general government, which in many instances they supplemented by large appropriations of their own, and the volunteer militia continued to increase in numbers and efficiency until the breaking out of the "war of the rebellion." Of that fearful struggle it is safe to say that the magnificent armies which were so quickly formed on both sides were only made possible by the fact that the efforts of regularly educated officers in drilling and disciplining them were supplemented by those who had received a partial military training in the volunteer militia.

Just before the war, in 1860, an earnest effort was made in the House of Representatives to increase the annual appropriation for furnishing arms and equipments to the militia. In urging the measure, Mr. Vallandigham reviewed the militia system and spoke of the volunteer system replacing it, asserting that they would "in time become the National Guard of America."

After the close of the "war of the rebellion" another most decided effort was made, both in the House and Senate, to reorganize the militia, or rather to create a new militia system, and several bills for that purpose were introduced in the Thirty-ninth Congress. Although none of these bills were passed, they contained provisions that are interesting and suggestive, and some that went to the extreme limit, if they did not go beyond the constitutional power of Congress in the premises. It was,

however, a purpose common to all the bills to form an active volunteer militia, and that seemed to be accepted as the true solution of the militia question.

This closes the history of the efforts to achieve a satisfactory militia system, with the exception of an interesting report by the Chief of Ordnance (S. Ex. Doc. 22, second session Forty-fifth Congress), and a report by the Senate Committee on Military Affairs (S. Report 56, second session Forty-fifth Congress), both recommending that the permanent appropriation for providing arms and equipments for the militia be increased to $1,000,000 a year.

Whether your committee have gleaned any wisdom from their examination of the history of this question which will make their solution of it worthy of your attention, or whether our efforts will simply mark another era in the history of futile attempts to secure legislation on this important subject, remains to be seen.

Before proceeding to present our own conclusions and views on the subject, we deem it desirable that its premises should be thoroughly understood, and we therefore first present brief recitals of the details of the present law, of the details of proposed law, and of the leading points of difference between them, in the hope that they may enable an intelligent consideration of the matter.

DETAILS OF PRESENT LAW.

Sections 1625, 1626, 1627 for the enrollment of the militia are provided for in section 1 of proposed bill.

Section 1628, requiring every citizen to arm and equip himself, is obsolete.

Section 1629, giving list of persons exempt from militia duty, is unnecessary, as proposed bill provides solely for a volunteer militia. If reserve militia is ever called into service it would only be by act of Congress, which would specify the persons to be exempt from the call.

Sections 1630, 1631, 1632, giving in detail the organization of the militia, are provided for by the general provision in section 4 of proposed bill that their organization shall conform as closely as practicable to that prescribed for the Regular Army.

Section 1633, requiring officers to provide colors and music, is obsolete.

Section 1634, that there be an adjutant-general in each State, is provided for in section 11 of proposed bill.

Section 1635, prescribing what reports officers of the militia shall make, is omitted in proposed bill as a matter more proper to be regulated by the States.

Section 1636, requiring an annual report to be made by the adjutant-general of each State, is provided for in section 11 of proposed bill.

Section 1637, that system of discipline and field exercise shall be the same as in the Regular Army, is retained with verbal alterations as section 5 of proposed bill.

Section 1638, regulating seniority of commissioned officers of same rank, is retained as section 22 of proposed bill, with verbal alterations making it applicable only when militia is in the service of the United States.

Section 1639, that militia wounded in service shall be cared for at public expense, is provided for in general provisions of section 19 of proposed bill.

Section 1640, prescribing duties of brigade inspectors, is obsolete.

Provision for inspection of the militia is made in section 14 of proposed bill.

Section 1641, recognizing special privileges accorded by any of the States to existing organizations, is retained as section 6 of proposed bill.

Section 1642, authorizing President to order militia into service of the United States, is provided for in section 19 of proposed bill, and, in accordance with the theory of the bill, limited to the active or volunteer militia.

Section 1643, that the President, in calling out the militia, shall apportion it among the States, is omitted in proposed bill.

Section 1644, that militia in service shall be governed same as Regular Army, is provided for in general provisions of section 19 of proposed bill.

Sections 1645, 1646, 1647, prescribing how militia shall be organized when called into service, are provided for in section 4 of proposed bill.

Section 1648, that in calling out militia the President shall specify length of time, which shall not exceed nine months, is provided for in section 19 of proposed bill.

Section 1649, penalty for disobeying order calling into service, is provided for in section 20 of proposed bill, changing penalty to that prescribed for desertion.

Section 1651, prescribing when pay shall commence, is superfluous, and is omitted in proposed bill.

Section 1652, allowing one day's pay for every twenty miles' travel, is retained as section 21 of proposed bill, changing it to fifty miles.

Section 1653, regulating allowance for forage and use of horses in service, is changed and provided for in section 23 of proposed bill.

Section 1654, to regulate liability for expense of marching militia to place of rendezvous when called into service, is surperfluous, and is omitted in proposed bill.

Section 1655, allowing militia called into service on western frontier extra rations, is obsolete.

Section 1656, that pensions shall be allowed to widows and children of militiamen, is provided for in the general provisions of section 19 of proposed bill.

Section 1657, allowing pensions to volunteers and militia who were disabled in service against Florida Indians, is obsolete, and belongs to the general pension laws.

Sections 1658, 1659, 1660, that courts-martial for the trial of militia shall be composed of militia officers only, and providing for the collection of fines imposed, are omitted in proposed bill, as applicable only when the militia are in the service of the United States, and it is provided that when in service they shall be governed by the rules and regulations of the army.

Section 1661 makes a permanent appropriation of $200,000 a year to provide arms and equipments for the militia. Sections 6 and 7 of the proposed bill abolish this system, and provide that the active militia shall be fully armed and equipped, and leave it in the hands of Congress to make annual appropriations for that purpose.

DETAILS OF PROPOSED LAW.

Section 1 provides that all citizens between eighteen and forty-five years of age shall be enrolled in the militia. This is existing law.

Section 2 divides the militia into two classes—the active and inactive.

The purpose of this division is to recognize the volunteer militia of the States as the militia *de facto*. As this is the key of the proposed change in the militia system, we shall consider it more in detail further in this report.

Section 3 provides that the active militia shall consist of the militia organized under the laws of the respective States. As the term of enlistment in the volunteer militia varies under the militia laws of different States, it is deemed desirable to add the proviso that to entitle them to arms and equipments the enlistment shall not be for a less period than three years. In order to prevent any question that might arise if the term of enlistment of a militiaman should expire while he is in the service of the United States, a further proviso is added that his enlistment shall contain a condition to cover that contingency.

Section 4 provides that the organization of the active militia shall conform as closely as practicable to that of the Regular Army.

Section 5 is a clause similar to existing law to provide that same system of drill and tactics shall be used by the active militia as is prescribed for the Regular Army.

Section 6 is a transcript of clause in existing law to provide for recognizing as a portion of the active militia any privileged volunteer organizations that exist in the States.

Section 7 specifies the kinds and amounts of arms, equipments, uniforms, and camp equipage that shall be furnished by the general government to the active militia, and is an important feature in the proposed change in the militia system, as it substitutes these specifications for the existing permanent appropriation of $200,000 a year for this purpose. As the States have already in possession arms and equipments heretofore issued, and as many of the States have largely overdrawn their accounts in the annual allotment of the permanent appropriation, a provision is added to this clause to release the States from any liability for their overdrawn accounts, and to require them to account for the property now in possession as a part of the allowance made by this act. As the bill provides that the active militia shall be armed and equipped by the general government, it is required of the States, to entitle them to the benefits of the act, that they shall comply with the provisions deemed necessary to make it efficient and available whenever its services may be required by the general government. But in order that immaterial departures from the requirements of the law, or failure under excusable circumstances to comply with them, may not be construed to the prejudice of the militia, a discretionary power is left with the Secretary of War to authorize the issue, if he deems it advisable.

Section 8 provides that the Secretary of War shall include in his annual estimates the amount of money required to carry out the provisions of the bill, and places the whole matter of supplying the militia in charge of the Ordnance Department, under his direction.

Sections 9 and 10 provide for accountability by the States for property issued to them, and supply one of the manifest deficiencies of the existing law, which makes no provisions on the subject.

Sections 11 and 12 provide for annual returns to be made, in order that Congress may be fully advised of the condition and needs of the militia, and the Executive at all times in posession of necessary information as to its availability for service.

Section 13 prescribes and limits the use of the service uniform by the active militia.

Section 14 provides that to entitle them to to be provided for by the general government, the active militia shall assemble in camps of in-

instruction annually, and be annually inspected. These provisions are most important, as it is only through their agency that the militia can be brought to that state of efficiency that would justify the government in the expenditure necessary to maintain it.

Section 15 provides that officers of the Regular Army shall be present at the annual inspections of the militia, to make observations as to their efficiency and to examine the condition of the public property in their possession. The section carefully guards against any exercise of unconstitutional authority in the premises, and is not only deemed essential but is also earnestly desired by the militia.

Sections 16 and 17 have for their object the encouragement of rifle practice, and for such competition between the Militia, the Regular Army, and the Navy, as must result in great benefit to each. This subject is now so well understood, and has become a matter of so much national pride, that argument in favor of it is unnecessary.

Section 18 provides that officers of the Regular Army may be detailed to serve as adjutants in the active militia. This provision is earnestly desired by the militia, and as it can be complied with without expense to the government, and when availed of must result in such great benefit to the militia, it is deemed a wise provision. In large cities in which regiments of active militia exist as "live organizations," the administrative business of the regiment is so great that it is almost impossible to find officers who can spare the time from their daily avocations to discharge it. There is not only no compulsion in the provisions of the section, but careful provision to the contrary. It is obvious that supernumerary and unemployed officers of the Regular Army, who have been educated in their profession at the public expense, cannot be better employed than in assisting the efforts of the militia to attain efficiency, whenever the militia request it.

Sections 19, 20, 21, 22, and 23 make the necessary provisions for authorizing the President to order the active militia into the service of the United States, and for governing them while in the service. These provisions do not differ materially from existing law, except that they are better arranged and more concise, and are made applicable to the active militia only.

Section 24 provides that the reserve militia shall only be called into service by act of Congress. No contingency could arise in which it would be proper to call out the unarmed, unorganized, and untrained mass of the population without some legislation by Congress to provide specially for it.

Section 25 provides for the appointment of a board of officers to prepare a system of rules and regulations for the discipline of the militia, to select a uniform, and to determine the kind and amount of ammunition and camp equipage that shall be allowed to the militia.

Section 26 makes an appropriation for the ensuing fiscal year. As the bill repeals existing appropriation, unless an appropriation is made in the bill the militia would be without any supplies whatever during the year intervening before the regular estimates of the Secretary of War would be appropriated for.

DIFFERENCES BETWEEN EXISTING LAW AND PROPOSED LAW.

From the foregoing statements of details, it is apparent that the leading features of difference between existing law and proposed law are as follows:

First. To substitute a volunteer militia, limited in number in time of

peace, for the existing compulsory system that applies to the whole body of the people, and which has become so inapplicable as to be utterly disregarded.

Second. To make such provisions as will aid and encourage the formation of volunteer organizations, remove the disparity in their numbers and discipline that exists between different States, and promote their efficiency to a common standard that will make them available for all the purposes for which a militia is required.

Third. To abolish the present system of a permanent appropriation to provide arms and equipments for the militia, and substitute provisions prescribing with what arms and equipments the militia shall be furnished, and on what conditions—leaving it in the discretion of Congress to regulate the annual appropriations for that purpose.

If these three leading points are agreed upon as the proper remedy for the defects in the militia system, the details necessary to carry them into effect will not require much discussion.

In relation to the first feature, the substitution of the volunteer system, the brief sketch we have given of the history of the militia law will have made it apparent that the chief defect of the existing system was early recognized to be in the excess of numbers held to militia duty by it. As the country increased in population this excess of numbers correspondingly increased, until the law has now become a practical absurdity by requiring to-day actual militia service from six and one-half millions of men. We have seen that for more than half a century the best and wisest statesmen of our country endeavored to procure agreement to some plan that would limit the militia to a practicable number, in order that it might be made an effective body. The more the country increased in population, and the more the population became absorbed in the pursuit of wealth and material prosperity, the more impracticable became the provisions of the militia law, until finally it sunk into such utter contempt that all pretense of regarding it ceased. The "cornstalk militia" and the annual "trainings," with all their accompanying parodies on military efficiency, remain only as recollections of our boyhood days. Volunteer organizations gradually increased as regard of existing law decreased, and, though unrecognized by the general law, and without any of the aids or requirements necessary to secure efficiency, they have managed to maintain a precarious existence, and have unquestionably been of great and essential service to the country. We think it good policy and true statesmanship to acknowledge the changes and avail ourselves of the results which time and the force of circumstances have brought about, and we therefore assent to the proposition that the volunteer militia of the States—the militia in fact—should be recognized as the militia of the law, and provided for accordingly.

On the second feature of the bill, the provisions made for promoting the efficiency of the volunteer militia and securing a uniformly high standard in all the States, we believe that there can be no disagreement.

The unorganized levies which, under the name of militia, have been called into service in all the great wars of the country, while they occasionally performed some brilliant service, have not only shown the inefficiency of existing law, but have also served to make the term "militia" one of contempt and derision. It is not denied that great disparity exists in the character and efficiency of the existing volunteer organizations between the States and even within the States. During the "labor riots of 1877" some volunteer organizations proved utterly undisciplined and unreliable, while others performed conspicuous and valuable service. Congress has never exercised its constitutional power

"to provide for organizing, arming, and disciplining" the volunteer militia. On the contrary, the volunteer organizations have maintained themselves at their own expense, with such aid as by unwearied exertions they may have been able to procure from their respective States. It is due solely to the want of support and of uniform requirements as to drill and discipline that the volunteer organizations have not all reached the same efficiency that characterize a part of them. The men who constitute the volunteer organizations are naturally those who have some love or aptitude for military affairs, and we therefore see no reason why, under proper regulations for their discipline and training, they cannot attain a high and uniform efficiency. That they have been or are in any particulars inefficient is not an argument against the possibility of making them all that we desire. We therefore consider the provisions made in the proposed bill, to aid and encourage the volunteer system and to exact certain requirements of them, as both politic and wise. We deem them politic, for the reason that the aid they offer is conditioned on the volunteers complying with the provisions which are deemed essential to their efficiency. We deem them wise, for the reason that we believe that under their operations a volunteer militia will be created, which, although remaining under the exclusive control of the States, will, when its services are required by the general government, be found ready and equipped for instantaneous service and fully efficient to perform the duties of militia, which Jefferson defined to be "not only to meet the first attack, but, if it threatens to be permanent, to maintain the defense until regulars can be engaged to relieve them." It is also worthy of consideration that in encouraging the volunteer system you provide for disseminating military knowledge and a partial military training among those who would be most likely to respond to a call for volunteers in time of war.

It has been agreed by all who have preceded us in considering the subject that, whatever might be the expense of securing an efficient militia, it would be so small, as compared with the benefits to be derived from it, that it should not be considered, and would in fact be covered by indirect savings of expense which it would render practicable in other directions. Nevertheless, your committee have deemed it proper to endeavor to form some estimate of the expense of the aid proposed to be extended to the volunteer militia by the bill under consideration.

While the States have applied all the existing permanent appropriation for the militia to providing the volunteer militia, the issue of property under that appropriation is limited to arms and equipments. This has been not only the greatest obstacle to the advancement of the volunteer militia, but has also prevented them from being useful on the occasions that their services have been required. Tents and camp equipage are absolutely necessary to enable the volunteers to go into camps of instruction and learn the elementary duties of soldiers. A plain, serviceable, and unostentatious uniform, overcoats, blankets, haversacks, canteens, &c., are essential to the outfit of the volunteer, that he may be called into service at a moment's warning, and that his services may be effective when called for.

We quote the latest report of the Secretary of War on the subject (Ex. Doc. H. R. 36, second session Forty-sixth Congress) for information of the number of militia:

Abstract of the militia force of the United States (organized and unorganized), according to the latest returns received at the office of the Adjutant-General, United States Army, furnished for the information of the Congress of the United States in compliance with section 232 of the Revised Statutes.

States.	Organized strength.								Number of men available for military duty (unorganized).
	Year.	General officers.	General staff officers.	Regimental, field, and staff officers.	Company officers.	Total commissioned.	Total non-commissioned officers, musicians and privates.	Aggregate.	
Maine	1878	1	10	9	41	61	814	875	78, 458
New Hampshire	1879	1	8	27	107	143	1, 805	1, 948	48, 770
Vermont	1879	1	14	12	38	65	605	670	44, 366
Massachusetts	1879	2	17	95	215	329	3, 699	4, 028	225, 461
Rhode Island	1878	4	35	76	99	214	1, 764	1, 978	42, 969
Connecticut	1879	7	15	37	134	193	2, 895	3, 088	73, 961
New York	1879	19	205	264	851	1, 339	18, 941	20, 280	567, 669
New Jersey	1878	3	35	67	130	235	2, 983	3, 223	248, 127
Pennsylvania	1879	6	56	174	451	687	9, 063	9, 750	422, 371
Delaware	1879	3	4	1	6	14	76	90	24, 073
Maryland	1879	1	8	6	66	81	1, 164	1, 245	89, 344
Virginia	1879	1	1	22	161	185	2, 450	2, 635	*215, 200
West Virginia	......	......	......	......	......	......	......	......	*100, 000
North Carolina	1879	7	18	41	196	262	2, 521	2, 783	*200, 000
South Carolina	1879	16	162	67	748	993	10, 812	11, 805	95, 856
Georgia	......	......	......	......	......	......	......	......	*180, 000
Florida	1878	8	50	100	215	373	5, 130	5, 503	25, 903
Alabama	......	......	......	......	......	......	......	......	*170, 000
Mississippi	1879	7	2	......	......	9	......	9	135, 178
Louisiana	1879	5	5	47	149	206	2, 551	2, 757	137, 973
Texas	1879	1	1	1	84	87	1, 119	1, 206	*150, 000
Arkansas	1877	14	32	197	710	953	15, 424	16, 377	*100, 000
Kentucky	1879	......	1	4	43	48	674	722	218, 000
Tennessee	1876	1	6	......	72	79	1, 205	1, 284	239, 564
Ohio	1879	1	16	114	400	531	7, 343	8, 374	500, 000
Indiana	1879	......	8	......	72	80	1, 464	1, 544	320, 546
Michigan	1879	5	12	23	71	111	1, 688	1, 799	*300, 000
Illinois	1879	3	51	107	387	548	6, 846	7, 394	*350, 000
Missouri	1879	1	4	5	67	77	1, 270	1, 347	*300, 000
Wisconsin	1879	3	6	5	78	92	1, 732	1, 824	*250, 000
Minnesota	1879	1	3	1	8	13	191	204	*120, 000
Iowa	1877	1	11	50	269	331	4, 250	4, 581	197, 456
Nebraska	1879	1	1	......	36	38	658	696	46, 000
Kansas	1879	5	5	11	106	127	1, 920	2, 047	121, 070
Nevada	......	......	......	......	......	......	......	......	*20, 000
Oregon	1878	3	24	......	32	59	582	641	14, 878
California	1879	7	88	42	120	257	2, 340	2, 597	114, 565
Colorado	1878	6	7	......	36	49	553	602	29, 000
Grand aggregate.	......	145	921	1, 605	6, 198	8, 869	117, 037	125, 906	6, 516, 758

*Estimated in Adjutant-General's Office.

E. D. TOWNSEND,
Adjutant-General.

ADJUTANT-GENERAL OFFICE,
Washington, D. C., January 31, 1880.

From this report it will be seen that there now exists, on paper, an organized volunteer militia of 125,906. The proposed bill limits the number that the general government will provide for to about 200,000, and it is not considered probable that for some time to come an *actual* force of over 150,000 will require to be provided for.

The existing volunteer militia are more or less already provided with

what is essential. Some of the States have made very large appropriations to supplement the amount heretofore allowed by the general government, and many of the States, as we have before mentioned, have now in possession considerable amounts of arms and equipments that have been issued to them by the general government. It is therefore difficult to estimate what would be the cost of making up deficiencies, and of completing the arming and equipment and of providing uniforms and camp equipage for the volunteer militia in the manner contemplated by the bill, but we judge that three million dollars would be ample for that purpose, and that its appropriation might be distributed into the budget of three successive years. After the volunteer militia should be once completely armed and equipped, we judge that an annual expenditure of $750,000 would maintain it in proper condition. These sums are comparatively very small, scarcely large enough to excite either opposition or comment, being smaller than was frequently contemplated and advocated in the early days of the Republic. The annual expenditure would be less than is required to sustain a regiment of cavalry in the regular service, and it cannot for a moment be questioned that a standing force of 150,000 thoroughly armed, equipped, and well-drilled volunteers, ready to take the field at the first moment of danger, would be as effective in the national defense as one regiment of regulars, and that the existence of such a force would be seriously considered by any nation contemplating an attack on us. In this connection it is not improper for us to observe that the Senate Committee on Military Affairs in the Forty-fifth Congress (Senate Report 56, second session Forty-fifth Congress) recommended that the annual appropriation for the militia be increased to $1,000,000, very pertinently observing that "if $200,000 was none too much in 1808, certainly $1,000,000 is none too much now."

On the third general feature of the bill, that of abolishing the permanent appropriation and placing the requirements of the militia on the same footing as all other needs of the government, to be annually estimated and to be appropriated for in the discretion of Congress, the committee do not deem any arguments necessary.

While the proposed bill scarcely involves the

POWERS OF CONGRESS AND RIGHTS OF THE STATES,

your committee deem it proper to present its bearings on those points, in order that no question may arise in regard to them.

There is no feature in our form of government in which the powers of the general government and the rights of the States are so intimately interwoven as in the jurisdiction over the militia. One of the stated primary causes for forming the Union was to "provide for the common defense." In the opinion of the framers of the Constitution, a well-regulated militia was the essential means of providing for the common defense, and they accordingly framed the clause to provide that Congress shall have power—

> To provide for organizing, arming, and disciplining the militia, and for governing such part of them as may be employed in the service of the United States, reserving to the States respectively the appointment of the officers, and the authority of training the militia according to the discipline prescribed by Congress.

The purposes and provisions of this clause are clearly and distinctly stated and scarcely admit of misinterpretation. The States are expressly limited to the appointment of the officers and to training the militia, and in training it according to the discipline prescribed by Con-

gress. If the power conveyed to Congress by the words "organizing, arming, and disciplining" could be doubted, the debates of the Federal Convention are sufficiently clear to remove them. The committee that reported the clause, on being asked the scope of the powers that they intended to convey, replied that they meant by "organizing," proportioning the officers to the men; by "arming," not only to provide for uniformity of arms, but the authority to regulate the modes of furnishing them, either by the militia themselves, the State governments, or the national Treasury; and by "disciplining," to prescribe the manual exercise, evolutions, &c., and that laws for disciplining must involve penalties and everything necessary for enforcing penalties.

The debates of the Federal Convention on adopting the clause, though short, are pertinent.

Mr. Mason, who introduced the subject, thought that all power over the militia should be vested in the general government, which he subsequently modified by suggesting that this absolute power should be limited to a portion of the militia at a time, so that by serving in rotation the whole body would finally be disciplined.

Mr. Madison thought that the regulation of the militia naturally appertained to the authority charged with the public defense, that it did not seem in its nature divisible between two distinct authorities, and that the discipline of the militia is evidently a national concern, and ought to be provided for in the national Constitution.

The clause as reported by the committee had but little opposition, it being conceded, as stated by Mr. Randolph, that reserving to the States the appointment of the officers was all the security they needed. Mr. Dayton and Mr. Ellsworth expressed themselves in favor of placing greater limitation on the power of Congress, but a motion made for that purpose received only one vote, that of Mr. Ellsworth, who moved it, and the clause, as it now stands, was therefore adopted with a marked unanimity in sentiment and vote.

We have only adverted to the question of the constitutional power of Congress as a matter of historical interest in connection with the general subject, for whatever question there may be as to the constitutionality of the existing law, or of some of the plans heretofore suggested for reorganizing the militia, none can possibly arise on the proposed bill, for it is a happy solution of all the constitutional questions involved. There is not a compulsory feature in the bill. It simply says to the States that if they will by their own laws provide for and enforce such requirements as Congress deems necessary to secure an efficient militia, Congress will exercise its unquestioned constitutional power, and provide for arming such militia out of the national Treasury.

GENERAL CONCLUSIONS.

From this review of the subject your committee are satisfied that time has solved those difficulties of the militia system for which the wisdom of our predecessors could find no acceptable remedy, and that the great increase in the population of the country now makes it not only practicable but desirable to substitute the volunteer system for enforced militia duty in time of peace. The subject is one on which there never have been any political differences, and on which none should exist. Washington, as the exponent of the Federalists, was unceasing in his efforts to procure legislation, and Jefferson, as the leader of the Anti-Federalists, was even more importunate in urging it. In view of these

facts, and of the fact that we now have practically no militia system, and that the strength and perpetuity of our republican form of government largely depend on the existence of a well-regulated militia, we indulge the hope that the subject will receive the earnest consideration which it deserves, and that some decisive action will be taken on it.

A BILL to provide for reorganizing, arming, and disciplining the militia.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That every able-bodied male citizen, resident within the respective States and Territories, between the ages of eighteen and forty-five, shall be enrolled in the militia, and said enrollment shall be made at such times and in such manner as may be provided by the laws of each State and Territory respectively.

SEC. 2. That the militia shall be divided into two classes: the active, to be known as the National Guard; and the inactive, to be known as the Reserve Militia.

SEC. 3. That the National Guard shall consist of such regularly uniformed and enlisted troops in the several States and Territories as are or may be organized therein in pursuance of the laws of the respective States and Territories: *Provided, however,* That the term of enlistment in no State or Territory shall be for a less period than three years, and with the provision that if such enlistment should expire during a time when in the service of the United States that it shall continue until the expiration of the time for which called into such service.

SEC. 4. That in time of peace the organization of the National Guard, the numbers, rank, and duties of the staff officers, and the organization of bureaus of administration, in the militia of the several States and Territories, shall be such as the legislatures thereof may from time to time direct: *Provided, however,* That such organization shall conform as closely to the method prescribed for the Regular Army as the circumstances of the various States and Territories will permit: *And provided further,* That when called into the service of the United States, the National Guard may be organized by the President into brigades and divisions, as the public interests may, in his opinion, require; and he may assign and designate the commanders of such brigades and divisions; and the numbers, rank, and duties of the staff officers shall be the same as prescribed for the Regular Army.

SEC. 5. That the active militia shall be trained in accordance with the same system of tactics that may from time to time be prescribed for corresponding arms of the service in the Regular Army.

SEC. 6. That all corps of artillery, cavalry, or infantry, now existing in any State or Territory, which, by any law, custom, or usage thereof, have not been incorporated with the militia, or are not governed by the general regulations thereof, shall be allowed to retain their accustomed privileges, subject, nevertheless, to all other duties required by law in like manner as the other active militia; and any State or Territory in which such corps may exist shall be entitled to include the same in the number and as part of the active militia for which it is entitled to receive the benefits of this act.

SEC. 7. That in time of peace each State and Territory complying with the provisions of this act shall be entitled to be furnished with small-arms, field artillery, and harness, infantry, cavalry, and horse equipments, and service-dress sufficient to fully arm, equip, and uniform its actual number of regularly enlisted active militia, and with such allowance of ammunition and such kinds and allowance of camp equipage as shall be prescribed by the board of officers to be appointed for that purpose: *Provided, however,* That the number of active militia for which any State or Territory shall be entitled to be so furnished shall not exceed seven hundred regularly uniformed commissioned officers and enlisted men for each Representative or Delegate to which such State or Territory is entitled in the Congress of the United States: *And provided further,* That all serviceable arms and equipments that have heretofore been furnished by the United States, and are now in possession of the respective States and Territories, shall be counted as part of this allowance, and shall be annually accounted for in the same manner as herein provided for arms and equipments hereafter issued; and that all accounts existing between the States and Territories and the United States for arms and equipments furnished the militia prior to the passage of this act shall be considered as closed and settled: *And provided further,* That if any State or Territory shall fail to comply with those provisions of this act on which the issue of arms and equipments for its active militia are conditioned, if such failure or omission is, in the opinion of the Secretary of War, immaterial or unavoidable, he may authorize such issue.

SEC. 8. That the Secretary of War shall include in his annual estimates of appropriations an estimate of the amount of money required to carry out the provisions of

this act; and the purchase or manufacture and the issue to States and Territories of small-arms, field artillery and harness, infantry, cavalry, and horse equipments, service dress, ammunition, and camp equipage, for the active militia under the provisions of this act, shall be made by the Chief of Ordnance of the Army, under the direction of the Secretary of War, and they shall remain the property of the United States, and be annually accounted for to the Chief of Ordnance of the Army by the governors of the States and Territories, for which purpose the Chief of Ordnance of the Army, under the direction of the Secretary of War, shall prescribe and supply the necessary blanks, and make such regulations as he may deem necessary to protect the said property of the United States.

SEC. 9. That loss of, or damage to, arms, equipments, ordnance stores, and camp equipage, except the ordinary wear and accidents of service, shall be made good to the United States by the person or persons chargeable therewith, as in like cases in the Regular Army; and money received from sales or on account of loss or damages shall be accounted for to the Chief of Ordnance of the Army, and paid into the Treasury of the United States.

SEC. 10. That all arms, equipments, ordnance stores, or camp equipage which may become unserviceable or unsuitable, shall be examined by a board of officers of the National Guard, and its report shall be forwarded by the governor of the State or Territory direct to the Chief of Ordnance of the Army for the action of the Secretary of War, who shall direct what disposition, by sale or otherwise, shall be made of them.

SEC. 11. That there shall be an adjutant-general in each State and Territory, who shall perform such duties as may be prescribed by the laws of each State and Territory, respectively, and who shall, on or before the last day of October in each year, make a return to the War Department, in such form as shall from time to time be prescribed by the Secretary of War, of the number of enrolled militia, the number of enlisted, organized, and uniformed active militia, of the results of the annual inspection of the active militia and military property in each State, and of the results and scores of the rifle practice of the active militia. He shall also make such special reports as may from time to time be required by the Secretary of War.

SEC. 12. That the Secretary of War shall, with his annual report of each year, transmit to Congress an abstract of the annual returns of the adjutants-general of the States and Territories, with such observations thereon as he may deem necessary for the information of Congress.

SEC. 13. That the service dress to be provided for the active militia, as herein prescribed, shall be worn when such active militia are called out for active service, and when in the performance of any duty, drill, parade, or ceremony prescribed by this act: *Provided, however,* That the same may also be worn at such other times as the military authorities of the State or Territory may direct: *And provided further,* That nothing in this act shall be construed to prohibit the wearing at other times of any full-dress uniform permitted by the military authorities of the States or Territories.

SEC. 14. That each State and Territory furnished with arms and equipments under the provisions of this act shall require every organization in its active militia to go into camp of instruction for at least five consecutive days in each year, and to assemble for drill and instruction not less than once in each calendar month, and shall require an annual inspection of its active militia, to be made by an officer or officers thereof, whose duty it shall be to report the result of such inspection to the adjutant-general thereof, stating the number of such active militia, the actual condition of their arms, accouterments, ammunition, and equipment, their deficiencies, and every other particular relating to the advancement of their organization and discipline.

SEC. 15. That notice shall be given by the adjutant-general of each State and Territory to the Secretary of War of the time and place of the annual inspections of the active militia of his State or Territory; and thereupon the President shall detail an officer from the active or retired list of the Army, to accompany the State inspector during his inspection, and observe the general condition of the troops and public property, with the consent and under the general direction of the governor of such State or Territory; and, while so detailed, retired officers shall, in addition to their pay as retired officers, be allowed and paid the actual traveling and other expenses incurred by them in the performance of the duty: *Provided, however,* That such officer shall have no authority in any way to control or interfere with the State inspector, or to exercise any power or authority during such inspection over the officers or men inspected. He shall make a report in duplicate, and transmit one copy to the governor of such State or Territory and another to the Secretary of War, of such matters as shall, in his judgment, require to be brought to their attention.

SEC. 16. That each State furnished with arms and equipments under the provisions of this act shall, within one year after the passage of this act, provide and equip at least one rifle range, and shall maintain the same for the instruction of its militia in rifle practice, and require them to be instructed therein.

SEC. 17. That the Secretary of War is authorized to offer annually to the National Guard of each State and Territory (provided they number at least seven hundred men)

a prize, not to exceed one hundred dollars in value, for competition in rifle practice; also to annually offer a prize of one thousand dollars to be shot for by a "team" or detachments from the National Guard of each State and Territory, from each of the three divisions of the Army, and from the Navy, to be divided among the three "teams" standing highest in such match.

The terms and conditions of both matches to be prescribed by the Secretary of War.

Each State team shall be certified to by the adjutant-general of its State, as consisting of its regularly enlisted and uniformed National Guard, and transportation to and from said last-named match shall be furnished out of such appropriation to such a team and reserve, not to exceed fifteen in number from each State, under such regulations as may be prescribed by the Secretary of War.

SEC. 18. That upon the application of any regimental, division, or brigade commander of the National Guard of any State or Territory, the governor thereof may apply to the Secretary of War to assign an officer from the active or retired list of the Army to act as adjutant of such regiment, or assistant adjutant-general or chief of staff of such brigade or division. Whenever the public interests will admit, the Secretary of War is authorized to assign such officer for such duty with his consent.

Officers so assigned shall be commissioned as officers in such National Guard by the governor of such State or Territory, and shall hold such commissions during his pleasure. While performing such duty, they shall give their entire time, or so much thereof as shall be necessary to properly perform the duties of their office; shall be subject to the rules and regulations of such National Guard while so assigned, and shall receive the full pay and emoluments of their rank as on detached service.

No assignment shall be made of any officer for this duty to the prejudice of the Regular Army, nor unless he shall have seen at least three years' service in the field. All such assignments may be revoked at pleasure by the Secretary of War, by giving notice thereof to the governor of the State. Upon receipt of such notice by the latter, the officer whose assignment is so revoked shall cease to be an officer of the National Guard of such State or Territory, and shall be honorably discharged therefrom by its governor.

SEC. 19. That the President of the United States may order the whole or any part of the active militia of any State or Territory into the service of the United States for a period not exceeding twelve months during war or an invasion, or apprehended invasion, by a foreign enemy or Indian tribe, or an insurrection or rebellion against the Constitution and laws of the United States, or upon the imminent danger of either, or on any occasion in which the execution of the laws may be obstructed by combinations and forces too strong to be overcome by the civil authorities in the ordinary course of law, and to issue his orders for that purpose to such officers of the active militia as he may think proper; and the said force, when ordered into the service of the United States, shall be subject to the rules and articles of war, and to the regulations of the Army, and shall be allowed the same pay, rations, and emoluments as are allowed to officers, non-commissioned officers, and privates of like grades and arms in the regular service; and in case of wounds or injuries received in the line of duty, or in case of being killed in the performance of such duty, the same provisions shall be extended to them, their widows and children, as are provided by law in like cases to officers, non-commissioned officers, and privates of like grades belonging to the Regular Army of the United States.

SEC. 20. That any officer or enlisted man of the active militia who, upon being ordered into the service of the United States, shall refuse or fail to obey said order without giving a valid excuse therefor, to be established by his oath and verified by the testimony of two credible and disinterested witnesses, may be tried by court-martial for desertion, and subject to the fines and penalties as in such cases provided.

SEC. 21. That the officers and enlisted men of the active militia called into the service of the United States shall be entitled to one day's pay, subsistence, and allowances for every fifty miles travel from their places of residence to the place of general rendezvous, and from the place of their discharge back to their residence.

SEC. 22. That when called into the service of the United States, officers of the same grade in the active militia shall take precedence according to the date of their commissions. In case two of the same grade have commissions of equal date, their rank shall be determined by lot, to be drawn by them before their commanding officer, unless their relative rank is prescribed by regulation.

SEC. 23. That mounted officers and members of mounted companies in the active militia called into the service of the United States shall each receive such consideration for use and risk of private horses actually used by them as may be awarded by a board of officers appointed by the Secretary of War. The same allowances of forage shall be made for private horses used by the militia in the service of the United States as for horses owned by the United States.

SEC. 24. That the Reserve Militia shall not be liable or subject to any military duty to the United States, except when called into service by act of Congress passed for that purpose.

SEC. 25. That as soon as practicable after the passage of this act, the President shall appoint a board of seven officers, two of whom shall be of the Army and five selected from the active militia of the Eastern, Middle, Southern, Western, and Pacific States, respectively. Said board shall prepare a system of rules and regulations for the discipline of the active militia, which rules and regulations shall be submitted by the President to Congress at its next ensuing session for approval and enactment. Said board shall also recommend a service-dress for the active militia, which, upon being approved by the President, shall be the uniform of the active militia when called into service. Said board shall also recommend an allowance of ammunition and the kinds and allowance of camp equipage to be issued to the active militia in time of peace, which, upon being approved by the President, shall govern the Chief of Ordnance in the issue of those articles under the provisions of this act. The five officers of said board appointed from the active militia shall, during the time they are engaged in the performance of the duties prescribed herein for said board, receive the pay and emoluments allowed by law to a colonel of infantry. The amount of money necessary for the payment of their services, and also for the payment of such expenses incurred by said board in the performance of its duties as may be approved by the Secretary of War, is hereby appropriated, to be paid out of any money in the Treasury not otherwise appropriated: *Provided, however*, That the total amount of money so to be paid shall not exceed three thousand dollars.

SEC. 26. That the sum of ——— dollars is hereby appropriated, out of any money in the Treasury not otherwise appropriated, for the purpose of carrying out the provisions of this act during the fiscal year ending June thirtieth, eighteen hundred and eighty-one.

SEC. 27. That sections sixteen hundred and twenty-five to sixteen hundred and sixty-one, inclusive, of the Revised Statutes, and all other acts and parts of acts inconsistent herewith be, and the same are hereby, repealed.

[Senate Ex. Doc. 22, Part 2, 45th Congress, 2d Session.]

Letter from the Chief of Ordnance in relation to the militia force of the United States.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, February 5, 1878.

DEAR SIR: I have the authority of the Secretary of War to transmit to you copy of my report on your resolution of the 13th December, 1877, in regard to the militia, and in advance of his response to the same.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

Hon. H. G. DAVIS,
United States Senate.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, January 10, 1878.

SIR: In answer to Senate resolution of December 13, 1877, I have the honor to report as follows:

The several points of inquiry embraced in the resolution may be expressed in the following interrogatories, viz:

1. What are the condition and number of the militia enrolled in the several States?

2. What recommendation has the Secretary of War to submit looking to a more thorough organization of the militia?

3. What recommendation looking to a more thorough collection of information and reports concerning the same?
4. What amount is annually apportioned to each of the States under section 1661, Revised Statutes?
5. Whether any State has received or been credited with more or less than its proportion of the sum annually appropriated, and what amount, if any, is now due any of the States?
6. If at any time any of the States have been excluded from the benefits of section 1661, what States, and for how long?
7. What kind of arms, and what articles are or can be furnished to the militia under the terms "arms and equipments"?
8. Should the amount annually appropriated be increased?

1. What are the condition and number of the militia enrolled in the several States?

This office is not possessed of the information requested in the first interrogatory. By section 1, act March 2, 1803 (sec. 1636, Rev. Stat. U. S.), the adjutants-general of the several States were required to furnish the President of the United States, annually, returns of the militia in their respective States, and of their arms, accouterments, and ammunition; and the Secretary of War was required to lay abstracts of these returns before Congress each year. Previous to 1862 these abstracts were submitted with the annual reports of the Adjutant-General of the Army, and were printed in the public documents; but since that year no abstracts of this character appear to have been published by Congress.

2. What recommendation has the Secretary of War to submit looking to a more thorough organization of the militia?

The subject of a more thorough organization of the militia of the country has engaged the attention of Congress at irregular intervals ever since the organization of the federal government in 1789. The Executive Documents and Reports of Committees of the two houses contain many reports upon the subject, and the Presidents' messages have often, in times past, invited attention to the subject.

The laws for the organization of the whole body of the militia, now incorporated in the Revised Statutes, were drawn from legislation had in the early years of the government, when the remembrance of the oppressions of the standing army of the mother country during the colonial period was fresh in the minds of the people, and when the prevailing sentiment was averse to a standing army forming a distinct class in the community. An energetic national militia has ever been considered as forming the capital security of a free people. (See the report of General Henry Knox, Secretary of War in 1790, in American State Papers, Military Affairs, vol. 1, p. 7; Art. II, Amendments to the Constitution; the spirit of the laws; and the utterances of statesmen from the foundation of the government to the present time.)

The present laws in many of their essential particulars, date from the period between 1792 and 1808, and have, in their application, special reference, in many respects, to the condition of things then existing; and consequently many have by time been rendered obsolete and inoperative. They, however, carry out, in their general scope and intendment, the initial idea that the Constitutional force for the national defense is the militia; and authority is given to the President to call forth such numbers, in time of invasion or rebellion, as the emergency may demand. Changes in these statutes as fix the details of organization, accountability, and armament are necessary.

3. What recommendation looking to a more thorough collection of information and reports concerning the same?

As early as 1794 a difficulty of primary importance in the execution of the militia act of 1792 was found in the requirement that the militia were to arm and equip themselves. At that period it was conceded in Congress that there was an insuperable difficulty in obtaining arms, there being but a limited supply in the country, with no manufactories, and no ability to obtain supplies from abroad. The only solid resource to obtain a supply was conceived to be the establishment of manufactories in each State. (See American State papers, Military Affairs, vol. 1, pp. 69, 70.) In 1794, Congress directed the establishment of three or four arsenals with a national armory attached to each, and laid an embargo on the exportation of all arms and warlike stores. The armory at Springfield, Mass., and that at Harper's Ferry, Va., were thereupon erected and placed in operation in the repair and manufacture of arms.

The militia were called upon by the President on several occasions between 1794 and 1808 for actual service; and Congress, by several acts during that period, authorized the purchase of arms, &c., for *sale* to the States, and to the individual militiamen called into service; and in some cases *loans* were authorized while in actual service, receipts being required in such cases as security for the faithful return to the government of the weapons to be used in its defense.

The inefficiency of the militia as a national institution was, during the period, directly traceable to the provision (Secs. 1628 and 1632, Revised Statutes) requiring the militiaman to provide at his own expense the arms and equipments which he might be called upon to use in the service of the general government. In 1807, a resolution was introduced in the House of Representatives expressing the sense that "provision ought to be made by law for arming and equipping the whole body of the militia of the United States," which, after protracted debate, was finally adopted. (See Annals of Congress, Tenth Cong., 1st Sess., vol. 1, pp. 1005, 1039, *et seq.*) A bill was accordingly presented for arming and equipping the whole body of the militia by appropriating $200,000 annually. The sum at first proposed—in view of the then meager supply of arms and equipments obtainable in the country and abroad (the wars in Europe having exhausted the foreign markets)—was $1,000,000; but this amount, as well as the successive sums of $500,000, $450,000, $400,000, and $300,000, was negatived, and the sum of $200,000 fixed upon (*Ibid.*, vol. 2, pp. 2191–2195), and has remained without alteration to this day. In 1816, by act of April 29, this amount was exempted from liability to be carried to the surplus fund.

After arms and equipments procured under the appropriation were received into the hands of the general government, they were placed in store in the various arsenals and armories, and were thence distributed to the States and Territories annually, in proportion to the number of the effective militia in their respective territorial limits. At first, only muskets (or rifles) and accouterments for the armament of the individual militiamen were procured or issued, but subsequently it was concluded to procure and issue light artillery, as might be required, in lieu of muskets, charging for the same in terms of "muskets," the apportionment and the accounts under the same being made and kept in those times in muskets.

A question was raised, in the debate on the original passage of the act of 1808, in regard to the *ownership* of the arms, &c., after they had passed out of the possession of the general government into the hands of the militia. This question was not settled by the terms of the act as it finally passed, and no action appears ever to have been taken by the War Department authorities to fix upon the State authorities or

the militiamen any system of periodical accountability for the arms, &c., issued to them. The procurement of the arms and equipments, the conveyance of them to the respective States, as called for, and the taking the receipts of the State authorities for the same, appear to have been all the duties recognized by the United States authorities as imposed on them by law. In 1874, upon a question raised in this office, the Attorney-General decided that "the statute makes no provision for any accountability whatever to the general government respecting the disposition of the arms when they have once been delivered to the States, Congress having seen fit to leave it entirely to the good faith of the latter, after the delivery takes place, to carry out the purpose contemplated in furnishing the arms." (Copy of opinion inclosed.)

OPINION.

DEPARTMENT OF JUSTICE,
Washington, November 11, 1874.

SIR: I have considered the question referred to me from your department on the 15th of September last, viz, "Whether, under existing laws, the right of property in the arms issued for arming the militia of the United States, is vested in the State authorities, with power to dispose of them by sale or otherwise, without accounting to the United States?"

This question, it would seem, from the papers submitted, has been suggested by facts of recent occurrence, which are especially connected with the quota of arms due, under the statutes relating to the arming of the militia, to the State of Virginia. It appears that the governor of that State made requisitions upon the Chief of Ordnance for about 2,307 revolvers, to be drawn as a portion of the said quota. To meet these requisitions, the latter officer, in July last, gave to an agent of the State orders upon the manufacturer for that number of revolvers, to be delivered within a short period thereafter. Upon receiving these orders, the agent, acting under the directions of the governor, proceeded to New York, and, in behalf of the State, entered into contracts with certain parties for camp equipage. It was agreed that the contractors should receive, in payment for the camp equipage furnished the State, under their contracts, an assignment of the aforesaid orders, and that the delivery of the arms, by the manufacturer, should accordingly be made directly to them. But I understand that the Chief of Ordnance, having information of this transaction, and conceiving that the right of the State to make such disposition of the arms, intended for the militia thereof, was not entirely free from doubt, directed the delivery of revolvers on said orders to be withheld until that point is determined; and the determination of that point has been thought to depend on the solution of the question referred to me.

The laws in force, which provide for the furnishing of arms to the militia, by the general government, are contained in the following sections of the Revised Statutes:

"SEC. 1661. The annual sum of two hundred thousand dollars is appropriated, to be paid out of any money in the Treasury not otherwise appropriated, for the purpose of providing arms and equipments for the whole body of the militia, either by purchase or manufacture, by and on account of the United States.

"SEC. 1667. All the arms procured, in virtue of any appropriation authorized by law, for the purpose of providing arms and equipments for the whole body of the militia of the United States, shall be annually distributed to the several States of the Union, according to the number of their Representatives and Senators in Congress, respectively; and all arms for the Territories and for the District of Columbia shall be annually distributed in such quantities, and under such regulations, as the President may prescribe. All such arms are to be transmitted to the several States and Territories by the United States.

"SEC. 1670. The Secretary of War is authorized and directed to distribute to such States as did not receive the same, their proper quota of arms and military equipments for each year, from eighteen hundred and sixty-two to eighteen hundred and sixty-nine, under the provisions of section sixteen hundred and sixty-one: *Provided*, That in the organization and equipment of military companies and organizations with such arms, no discrimination shall be made between companies and organizations on account of race, color, or former condition of servitude."

The provisions of the above-named sections have been taken from the act of April 23, 1808, ch. 55; the act of March 3, 1855, ch. 169; and the act of March 3, 1873, ch. 282.

By the first of those sections (sec. 1661), an annual appropriation is made "for the purpose of providing arms and equipments for the whole body of the militia." The next section (sec. 1667) provides for an annual distribution, among the several States and Territories, of the arms procured by means of such appropriation. It requires

these arms to be transmitted by the United States to the several States and Territories—the quota for each State to be according to the number of its Representatives and Senators, and the quota for each Territory, including the District of Columbia, to be according as the President may prescribe. The remaining section (sec. 1670) is only applicable to the particular case where a State did not receive its proper quota of arms and military equipments for any period from 1862 to 1869. It authorizes the Secretary of War, in that case, to distribute to such State its quota, for that period, subject to the proviso therein contained.

In none of the sections adverted to is there any provision which expressly vests the property in the arms, after their distribution, in the States absolutely; nor do I find anything therein from which such a change of ownership results by necessary implication. To get at the intent and meaning of the existing laws, with reference to that point, it seems therefore proper to recur to the earlier legislation on the subject of arming the militia, and particularly to that part of it from which the provisions in the Revised Statutes have been taken.

The power of Congress to legislate on that subject is expressly conferred by the Constitution (see Art. I, sec. 8, par. 16); and the first instance of the exercise of this power, by that body, is found in the act of May 8, 1792, entitled "An act more effectually to provide for the national defense, by establishing an uniform militia throughout the United States." (1 Stat., 271.) There it consisted simply in requiring each enrolled militiaman to "provide himself" with arms of a certain description. (See first section of that act.) This requirement is, however, reproduced in the Revised Statutes (see section 1628), and it constitutes now, as it did originally, what may be regarded the general law upon the subject of arming the militia—the other provisions of the Revised Statutes upon the same subject, to which reference has been made, being auxiliary, and not substitutive in their character.

Next followed the act of July 6, 1798, entitled "An act providing arms for the militia throughout the United States." (1 Stat., 576.) By this act thirty thousand stand of arms were authorized to be provided, at the expense of the Government of the United States, and "sold to the governments of the respective States, or the militia thereof," under such regulations and at such prices as the President might prescribe. But its object was only to meet an immediate want then felt by some of the States (especially the Southern), the people whereof were generally destitute of arms, and could not easily supply themselves therewith. It sought to facilitate the procurement of arms by the latter, to a limited extent, by enabling them or their respective States to purchase the same from the United States. The act of April 2, 1806, authorizing the sale of public arms to the States (2 Stat., 481), though it does not purport to have been passed with a view to arming the militia, is of a piece with the act of 1798, and contemplated similar objects.

The act of April 23, 1808, entitled "An act making provision for arming and equipping the whole body of the militia of the United States" (2 Stat., 490), is the first statute that contains provisions of a general and permanent nature for furnishing arms and equipments to the militia by the United States; and it deserves to be well considered here, for the reason that some of the more important of its provisions, directed to that end, are embodied in one or two of the sections of the Revised Statutes above quoted. The first section of the act is in substance the same as section 1661 of the Revised Statutes. It appropriates the sum of two hundred thousand dollars annually "for the purpose of providing arms and military equipments for the whole body of the militia of the United States, either by purchase or manufacture, by and on account of the United States." The third section declares that the arms procured in virtue of the act "shall be transmitted to the several States composing this Union, and Territories thereof, to each State and Territory respectively, in proportion to the number of the effective militia in each State and Territory, and by each State and Territory to be distributed to the militia in such State and Territory, under such rules and regulations as shall be by law prescribed by the legislature of each State and Territory." The rest of the act is not material in this connection.

The object of the annual appropriation made by this act is plainly expressed therein; it was to provide arms and equipments for the entire militia of the United States so far as such appropriations would enable this to be done. That object was contemplated to be carried out, partly through the agency of officers of the general government and partly through the intervention of the State authorities. Thus the procuring of the arms, with the means provided therefor, was, in the first place, to be done by officers of the United States, who were then to transmit the same to each State and Territory in proportion to the number of the effective militia thereof; whereupon the State and Territorial authorities were to distribute the arms so transmitted to them among the militia, in their respective States and Territories, under such rules and regulations as should be prescribed by the local laws. Accordingly, the States and Territories, with which arms were deposited under this act, must be deemed to have held them for a specific purpose only, and consequently (regarding the subject from a strictly legal point of view) to have had no right to divert them from that purpose by aliena-

tion or otherwise. They stood, as it were, in the situation of trustees, charged with the distribution of the arms, and had no other property therein than such as was necessary to enable them to perform that trust.

That the States and Territories, in contemplation of this statute, were to be vested with a qualified, not an absolute, ownership of the arms transmitted to them, is very manifest from its terms, which exclude the idea that a power to dispose of the arms, in any manner and for any purpose, such as would be incident to absolute ownership alone, was intended, by which the very object of the law, viz, the arming of the militia, might be frustrated altogether. A similar view was taken by the Senate in 1855, by which it was then thought necessary, in order to enable the States and Territories to sell the arms theretofore distributed under the act of 1808, to make provision therefor by statute, as impliedly appears from the action of that body in passing, by way of amendment to the Army appropriation bill then pending before it, a section which provided "that the governors of the several States and Territories be, and they are hereby, authorized to sell, to the best advantage, the arms heretofore distributed under the act of April 23, 1808, and invest the funds arising out of such sales in other arms more suitable for the purposes contemplated by said act: *Provided*, That no arms be so purchased or provided, except such as may be of the same description and caliber as those regularly adopted and in use in the Army of the United States." This amendment was not concurred in by the House, on the recommendation of the Committee of Ways and Means, and so it did not become a law. Yet while the negative action of the House cannot with certainty be attributed to a difference of view as to the power of the States and Territories over such arms under the then existing laws (for it may have proceeded from a doubt as to the expediency of the proposed measure,) the affirmative action of the Senate can assuredly be taken as an indication of its sense with respect to such power, and that was clearly this, that the power, whatever it might be, did not include the right to alienate the arms without the consent of Congress.

But to look at the subject from another stand-point: I have already adverted to the fact that the power of Congress to provide for the arming of the militia is expressly conferred by the Constitution. It is not maintained that this power is exclusively vested in Congress. It is merely an affirmative power, and if not in its own nature incompatible with the existence of a like power in the States, it may well leave a concurrent power in the latter; so that if Congress did not choose to make any provision for arming the militia, it would be competent to the States to do it in such manner as they might think proper. But when once Congress has carried this power into effect, its laws for the arming of the militia are the supreme law of the land, and all interfering State regulations must necessarily be suspended in their operation (Houston *v.* Moore, 5 Wheat., 51). Now, it appears that, in the exercise of this power, and with a view to provide for the national defense, Congress had undertaken to furnish arms for the militia at the expense of the general government. The kind and pattern of arms to be thus furnished were left to the determination of the officers of the general government, and hence such arms as were procured and transmitted by these officers to the States and Territories, for the militia thereof, must be regarded as arms specifically provided therefor by the paramount law. This being the case, is it not obvious that the State and Territorial authorities could not rightfully exchange those arms for others of a different kind or pattern, and distribute the latter to the militia in place of the former, or sell the arms so provided and invest the proceeds of the sale in other property which such authorities might conceive to be more needful to promote the efficiency of the militia? In either of these cases the action of the State and Territorial authorities would manifestly be in direct collision with the supreme law of the land.

Still it is to be observed that the statute under consideration made no provision for any accountability to the United States, in regard to the disposition of the arms, after their delivery to the State and Territorial authorities. When that took place the control of the officers of the general government over the arms ceased; and whether the future destination or use of the property was consistent with the design of the statute depended wholly upon the good faith of the States and Territories themselves. Practically, then, they might do what they pleased with it, though the disposition made of it by them should defeat the ends of the statute; for no way existed, as I conceive, to compel the execution of the trust devolved upon them.

By the seventh section of the act of March 3, 1855 (10 Stat., 639), the annual distribution of arms to the States, which, under the act of 1808, was made in proportion to the number of effective militia thereof was required to be made according to the number of their Representatives and Senators in Congress, respectively; and, in regard to the Territories and the District of Columbia, the arms were, by the same section, required to be distributed in such quantities and under such regulations as the President, in his discretion, might prescribe. These provisions are substantially embodied in section 1667 of the Revised Statutes. They modify the previous law no farther than to introduce a new basis for making distribution of the arms to the

States and Territories, which thenceforth took the place of the one originally prescribed.

Thus the law remained, touching the transmission of arms to the several States and Territories for the militia, up to the time of the adoption of the Revised Statutes; and I discover nothing in the provisions of the latter indicative of an intention on the part of Congress to clothe the States with any right of property in the arms thereafter to be transmitted to them other or different from that which they had in the arms theretofore deposited with them. The purpose of the annual appropriation thereby provided is the same precisely as was that of the similar appropriation provided by the statute formerly in force, viz, to furnish arms for the militia. The basis upon which the arms are to be distributed to the States is likewise the same as that previously established (*i. e.*, by the act of 1855 cited above), and they are required to be transmitted to the several States by the United States. It is true that, in the Revised Statutes, there is no clause expressly directing the arms to be distributed by each State to the militia thereof, as there was in the former statute; but the omission to insert any such clause therein is not to be understood as signifying an intent to relieve the States from that charge. The inference necessarily follows, from the declared purpose for which the appropriation for procuring the arms is made, that they are to be transmitted to the States for distribution among the militia, and for that object solely; and an express direction to that effect not being therefore really needed, it is probable that, for this reason, none was inserted.

Viewing the provisions of the Revised Statutes, above quoted, in connection with the previous legislation, I am unavoidably brought to the conclusion that, in contemplation of these provisions, the arms transmitted to the States thereunder are to be held by them for a specific purpose only, which is pointed out therein; that they therefore become, strictly speaking, invested with nothing more than a qualified property in such arms; and that they cannot, as a matter of right, and without thereby interfering with the regulations of Congress on a subject over which its authority is necessarily paramount, make any disposition or use of such arms which defeats the purpose referred to, though, if this should be done, there would seem to be no remedy without further legislation by Congress.

In answer, then, to the question propounded, I have the honor to state that, in my opinion, the States do not, by the existing laws, have "the right of property in the arms issued for arming the militia," if an absolute right of property is there meant, and that they derive no authority, under those laws, to sell or dispose of such arms at their pleasure. As I have already observed, the statute makes no provision for any accountability whatever to the general government respecting the disposition of the arms when they have once been delivered to the State; Congress having seen fit to leave it entirely to the good faith of the latter, after the delivery takes place, to carry out the purpose contemplated in furnishing the arms.

In regard to the actual case here presented, which concerns a part of the quota of arms due the State of Virginia, I may add that the disposition of the revolvers, hereinbefore mentioned, recently sought to be made by the authorities of that State, would clearly have been unwarranted by the existing laws of Congress on the subject of arming the militia. It was accordingly very proper for the Chief of Ordnance to withhold the delivery of the revolvers to the parties to whom the orders issued therefor had been assigned. He could not, under those laws, recognize any right in such parties to the revolvers. But the arms cannot be indefinitely withheld from the State, the statute requiring them not only to be annually distributed, but to be transmitted to it by the general government. After this is accomplished, the officers of the latter have nothing further to do with the arms so transmitted.

I am, sir, very respectfully, your obedient servant,

GEO. H. WILLIAMS,
Attorney-General.

Hon. W. W. BELKNAP,
Secretary of War.

4. What amount is annually apportioned to each of the States under section 1661, Revised Statutes?

The amount annually apportioned to each of the States and Territories under section 1667 Revised Statutes (not 1661, as stated in the Senate resolution) will be indicated for the fiscal year 1877 by the following table:

Apportionment of arms for the fiscal year ending June 30, 1877, under the law of 1808 for arming and equipping the militia, as amended by the seventh section of the act approved March 3, 1855, and regulations established in conformity therewith.

States and Territories.	Number of Senators and Representatives.	Money-value.
Alabama	10	$4,797 85
Arkansas	6	2,878 71
California	6	2,878 71
Colorado	3	1,439 36
Connecticut	6	2,878 71
Delaware	3	1,439 36
Florida	4	1,919 14
Georgia	11	5,277 64
Illinois	21	10,075 49
Indiana	15	7,196 78
Iowa	11	5,277 64
Kansas	5	2,398 93
Kentucky	12	5,757 42
Louisiana	8	3,838 28
Maine	7	3,358 50
Maryland	8	3,838 28
Massachusetts	13	6,237 21
Michigan	11	5,277 64
Minnesota	5	2,398 93
Mississippi	8	3,838 28
Missouri	15	7,196 78
Nebraska	3	1,439 36
Nevada	3	1,439 36
New Hampshire	5	2,398 93
New Jersey	9	4,318 06
New York	35	16,792 48
North Carolina	10	4,797 85
Ohio	22	10,555 27
Oregon	3	1,439 36
Pennsylvania	29	13,913 76
Rhode Island	4	1,919 14
South Carolina	7	3,358 50
Tennessee	12	5,757 42
Texas	8	3,838 28
Vermont	5	2,398 93
Virginia	11	5,277 64
West Virginia	5	2,398 93
Wisconsin	10	4,797 85
Arizona Territory*	3	1,439 36
Dakota Territory*	3	1,439 36
Idaho Territory*	3	1,439 36
Montana Territory*	3	1,439 36
New Mexico Territory*	3	1,439 36
Utah Territory*	3	1,439 36
Washington Territory*	3	1,439 36
Wyoming Territory*	3	1,439 36
District of Columbia	3	1,439 36
Total	396	189,995 00
Freights, &c	......	10,005 00
Total, being the appropriation for the fiscal year ending June 30, 1877	......	200,000 00

* Apportionment according to the first paragraph of the President's regulation of April 30, 1855.

The annual appropriation of $200,000 for arming and equipping the militia is disbursed by the Ordnance Department in the purchase and manufacture of arms and equipments. The appropriation may, at any given time, be all expended, and yet each State may be consistently said to have, at the very time, a money-value to its credit. The reason is this: Previous to the year 1864 the apportionments of the benefits of the law of 1808 to the several States and Territories for the militia within their limits were expressed on the militia books of issues in this office in terms of "muskets." This method had come down from 1808, when the theory of application of the law was the *armament of the individuals* composing the militia. When artillery and other military stores came subsequently to be issued, they were rated as equivalent to so many

"muskets." States were, therefore, in those times, said to have so many "muskets" to their credit; but in 1864, owing to the diversity of ordnance material that had come to be issuable to the militia, and the trouble of reducing everything to an equivalent of "muskets," the basis of "muskets" was abandoned, and the proper proportion of the benefits of the annual appropriation falling to each State and Territory was entered in *money-values* in the books of issues, and each State and Territory was thenceforward said to have so many $——— to its credit instead of "muskets." The entry of these money-values in the books of issues was to show that arms, &c., whose cost amounted to $——— on our books, could be drawn, and to prevent excessive issues by reducing all articles required and issued to a money standard. The money-values to the credit of a State at any time on these books of issues simply represented the muskets, or rifles, or artillery, or other quality of ordnance stores which that State was entitled to draw at pleasure, at stipulated prices, from the custody of the Ordnance Department. Sometimes a State would not draw any ordnance materials from the government for several years, when the *quantity of stores* to which it would then be entitled would be indicated by the sum of the annual apportionments which had in the mean time accrued to it.

The method of apportioning to the States their proper portions of the ordnance materials procurable under the annual appropriation, as indicated in the foregoing table by dividing the amount of the whole appropriation among them according to "*the number of Senators and Representatives of each in Congress*," was established by act of March 3, 1855, which also directed the distribution of arms to the Territories and District of Columbia in such quantities as the President might prescribe. These provisions are embodied in section 1667 Revised Statutes.

5. Whether any State has received or been credited with more or less than its proportion of the sum annually appropriated, and what amount, if any, is now due to any of the States?

During the period of the late war, as well as during the period subsequent thereto, when the States engaged in the rebellion were not represented in Congress, the apportionments or quotas falling due to those States were regularly entered up to their credit on the books of this office; and as these States drew no stores during the war, and very few subsequent thereto, the quantities to which they were entitled in 1870* were the accumulated values of several years. The following statement shows the money-values of stores which had accrued to them during the period of their non-representation in Congress, viz:

States.	Periods of non-representation.	Money-value of stores apportioned during the periods of non-representation.
Alabama	Years 1862-'63-'64-'65-'66-'67	$27,907 30
Arkansas	do	15,595 63
Florida	do	10,049 12
Georgia	do	31,252 67
Louisiana	do	22,299 38
Mississippi	Years 1862-'63-'64-'65-'66-'67-'68-'69	31,116 58
North Carolina	Years 1862-'63-'64-'65-'66-'67	31,258 67
South Carolina	do	22,337 83
Tennessee	Years 1864-'65	11,094 81
Texas	Years 1862-'63-'64-'65-'66-'67-'68-'69	24,408 82
Virginia	do	48,404 79
Total		275,725 60

* Except South Carolina, to whom $124,000 worth were issued in 1869, by authority of the Secretary of War, far exceeding the accrued quotas due at that time.

As it was questionable whether these States should be permitted to draw the arms, &c., which had accrued to them during the period of their non-representation in Congress, the act of March 3, 1873 (17 Stat. at Large, 608), specifically directed the distribution "to such States as did not, from the year 1862 to the year 1869, receive the same, their proper quota of arms and military equipments for each year from 1862 to 1869," and the States thereafter drew at pleasure for the arms and equipments which the above money-values represented. By March 3, 1875, most of them had drawn all or the greater portion of the arms above referred to, together with those which had accrued to them by intervening annual apportionments. But on the last-named date the act making appropriations for the support of the Army for the year 1876 directed, by a proviso to its third section, that—

So much of the *appropriations* between January 1, 1861, and April 9, 1865, under the act of April 23, 1808, herein referred to, as would have been used for the purchase of arms to be distributed to the several States that were in rebellion, shall be covered into the Treasury of the United States.

The effect of the last quoted law has been to deprive some of the States of the benefits of the act of 1873 (for instance, Alabama, $21,196.61; Florida, $7,314.99; North Carolina, $11,266.01; Tennessee, $11,094; South Carolina, $18,049.53), and I recommend that it be repealed.

No greater or less amount than the regular share of the annual appropriation of $200,000 is credited to any of the States or Territories on the books of issues in this office. In emergencies there have been issues of stores made (by special authority of the President or Secretary of War) in excess of the quantities due the States, and such issues have always been charged on their militia arms accounts against the States receiving the same.

During the late war extraordinary quantities of ordnance and ordnance stores were issued to the authorities of many of the loyal States for internal armament and defense, and the money-values of these stores were in all cases charged up on their arms accounts in the books of issues in this office. Many States were thereby charged with stores far in excess of what could be liquidated in any reasonable length of time by the apportionments annually falling due; and in March, 1875, the act for the support of the Army contained the following provision:

SEC. 3. That all issues of arms and other ordnance stores which were made by the War Department to the States and Territories between the first day of January, eighteen hundred and sixty-one, and the ninth day of April, eighteen hundred and sixty-five, under the act of April twenty-third, eighteen hundred and eight, and charged to the States and Territories, having been made for the maintenance and preservation of the Union, and properly chargeable to the United States, the Secretary of War is hereby authorized, upon a proper showing by such States of the faithful disposition of said arms and ordnance stores, in the service of the United States in the suppression of the war of the rebellion, to credit the several States and Territories with the sum charged to them respectively for arms and other ordnance stores which were issued to them between the aforementioned dates, and charged against their quotas under the law for arming and equipping the militia: *Provided*, That it shall be the duty of the Secretary of War, before making a credit to any of said States and Territories, to investigate and ascertain, so nearly as he can, the disposition made by each of said States and Territories of said arms and ordnance stores; and if he shall find that any of said arms or ordnance stores have been sold or otherwise misapplied, to refuse a credit to such State or Territory for so much of said arms and ordnance stores as have been sold or misapplied; and the amount thereof shall remain a charge against said State or Territory, the same as if this act had not been passed.

The following table shows the money-values of all stores issued to the several loyal States and Territories between the above given dates,

the credits which have been given under the terms of the law, and the money-values of stores issued between those dates which the States have not yet shown to have been used in the service of the United States, and for which credit has not been given in this office:

States.	Value of stores issued between January 1, 1861, and April 9, 1865.	Credit given under act of March 3, 1875.	Balances September 1, 1877.
California	$221,041 10	$182,281 51	$38,759 59
Connecticut	3,438 00	3,438 00	....
Delaware	20,431 00	17,000 00	3,431 00
Illinois	98,674 40	....	98,674 40
Iowa	923 00	923 00	....
Indiana	16,910 13	....	16,910 13
Kansas	44,231 00	44,231 00	....
Kentucky	1,139 00	....	1,139 00
Maine	13,959 25	13,959 25	....
Maryland	1,188 00	1,188 00	....
Massachusetts	25,210 00	25,210 00	....
Michigan	7,294 00	7,294 00	....
Minnesota	7,595 74	4,286 88	3,308 86
Missouri	5,330 00	....	5,330 00
New Hampshire	32,964 00	1,660 00	31,304 00
New York	107,246 00	106,292 00	954 00
North Carolina	5,896 00	....	5,896 00
Ohio	281,870 70	149,800 05	132,070 65
Oregon	14,416 57	....	14,416 57
Pennsylvania	1,327 00	1,327 00	....
Rhode Island	25,638 76	....	25,638 76
Tennessee	8,803 00	....	8,803 00
Vermont	638,358 37	28,537 22	609,821 15
Wisconsin	8,486 73	*8,486 73	....
Arizona Territory	1,982 50	....	1,982 50
Dakota Territory	10,022 34	....	10,022 34
Nebraska Territory	8,487 00	....	8,487 00
New Mexico Territory	45,251 00	....	45,251 00
District of Columbia	1,976 00	....	1,976 00
Total	1,660,090 59	595,914 64	1,064,175 95

*Full credit given this State January 2, 1878.

It has been represented to this office that in some cases States have sold some of these arms, &c., and placed the proceeds into the State treasury. As these sales took place after the war, and when the arms, &c., were comparatively worthless, the difference in value between what was received from the sales by the States and what was originally charged against them on our books was very great. It seems to me that justice demands that this difference be credited to the States on our books. With this view I submit the following as a draft of a bill that would cover the case:

That section 3 of the "act making appropriations for the support of the Army for the fiscal year ending June 30, 1876, and for other purposes," approved March 3, 1875, is so far modified as to direct the Secretary of War to make credit to any State that has sold arms or ordnance stores, of the difference of the amount charged for said arms or ordnance stores on the books of the Ordnance Office, and the amount received by the State from sales of said arms or ordnance stores.

The following statement shows the money-values of the ordnance stores due the States and Territories, or overdrawn by them, as ex-

hibited by the accounts of these several States and Territories on the book of issues in this office, on the date hereof, viz:

Number.	States and Territories.	Money-value of stores held subject to requisition of the States on January 10, 1878.	Money-value of stores overdrawn by States in excess of accrued apportionments on January 10, 1878.
1	Alabama	$5, 202 77	
2	Arkansas	9, 098 78	
3	California		$26, 984 56
4	Connecticut	135 63	
5	Delaware	16, 337 14	
6	Florida	962 18	
7	Georgia	10 28	
8	Illinois		11, 460 33
9	Indiaan	5, 994 10	
10	Iowa	1, 004 07	
11	Kansas	7, 488 55	
12	Kentucky	31, 226 16	
13	Louisiana	5 47	
14	Maine	7, 111 59	
15	Maryland	27 73	
16	Massachusetts	222 63	
17	Michigan	26, 000 98	
18	Minnesota	10, 181 01	
19	Mississippi	5, 417 04	
20	Missouri	11, 796 61	
21	Nebraska	1, 448 84	
22	Nevada	13 89	
23	New Hampshire		484 20
24	New Jersey	4, 357 56	
25	New York	39, 378 08	
26	North Carolina	1 29	
27	Ohio		43, 256 92
28	Oregon		5, 138 68
29	Pennsylvania		18, 512 67
30	Rhode Island		14, 783 24
31	South Carolina		84, 821 88
32	Tennessee	2, 057 00	
33	Texas		1, 199 35
34	Vermont		563, 038 48
35	Virginia	627 02	
36	West Virginia	4, 771 32	
37	Wisconsin	16, 749 00	
38	Colorado		8, 127 06
	Apportionment in conformity with paragraph 1 of President's regulation of April 30, 1855:		
	Arizona Territory		1, 597 53
	Dakota Territory		20, 957 25
	Idaho Territory	1, 440 29	
	New Mexico Territory		17, 192 01
	Montana Territory		48, 080 51
	Utah Territory	61, 734 59	
	Washington Territory	3, 840 59	
	Wyoming Territory	2, 895 87	
	District of Columbia	3, 758 45	

6. If at any time any of the States have been excluded from the benefits of section 1661, what States, and for how long?

The length of time during which any of the States have been excluded from the benefits of section 1661, Revised Statues U. S., has been stated in my answer to the fifth interrogatory.

7. What kind of arms and what articles are or can be furnished to the militia under the terms "arms and equipments"?

As has been before stated, the first issues made to the States and Territories under the act of 1808 consisted of muskets (or rifles) and accouterments, being the armament of the individual soldier. Subse-

quently light artillery and carriages were issued in lieu of small-arms, if so desired; and ammunition of all kinds has been issued to the States without reserve since the late war. At the present time, any article that is issuable to the Regular Army, and which may be in the custody of the Ordnance Department, or procurable by it, may be drawn by the State authorities.

8. Should the amount annually appropriated be increased?

The annual appropriation of $200,000 for arming and equipping the militia, fixed by the act of April 23, 1808, is entirely inadequate at the present time, with a population increased from eight to more than forty millions. As a consequence, some of the richer States of the Union have had to make appropriations of money to provide the arms, &c., necessary to supply such deficiency, although the intention of Congress, as expressed in the law of 1808, was that the money so appropriated should supply the "whole body of militia." If $200,000 was not deemed too much in 1808, when arms, &c., were cheap, as compared with the improved and costly mechanism now admitted to be a necessity, an increase of the appropriation to $1,000,000 annually will be required to fully meet the wants of the "whole body of the militia," and carry out the expressed wishes of Congress.

In further answer to the eighth interrogatory, I beg to invite attention to my remarks upon the subject in my Annual Report of October 5, 1877, page 7.

The Senate resolution is herewith returned.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brigadier-General, Chief of Ordnance.

APPENDIX 19.

TRIAL OF THE GARDNER MACHINE GUN BY THE ORDNANCE BOARD U. S. A.

COMPOSED OF LIEUTENANT-COLONELS S. CRISPIN AND T. G. BAYLOR AND MAJOR CLIFTON COMLY, ORDNANCE DEPARTMENT.

(Six plates.)

PLATE IV.

The Gardner gun, as submitted to the board and as shown with its carriage on the drawings herewith transmitted, consists of two breech-loading rifled barrels, caliber .45, chambered for the service cartridge, placed horizontally and parallel, 1.4 inches apart, which with the working mechanism are inclosed in a brass casing. By one complete turn of the hand-crank both barrels are loaded, fired, and the shells ejected. The barrels are held in position by rear and front barrel rings pinned to the case. The casing extends sufficiently from the rear barrel ring to contain the lock mechanism, together with the *driving crank* and *safety stop*. A swinging cover, hinged immediately over the rear barrel ring, gives easy access to all working parts of the gun in case of defective cartridges, derangement of locks, or other accident. The cover when closed is secured in position by a few turns of the cascable, which for that purpose has a screw-thread cut on its neck or stem entering the rear of the case. The hand-crank that operates the gun is pinned fast to the *main crank*, which is supported by journal boxes. The boxes are locked into the rear case, and serve as a protection to the swinging cover from side thrusts. The body of the *main crank* is circular, having journals or crank-pins for operating the locks diametrically opposite each other—the firing being alternate—and eccentric enough to give the required motion to the locks as they are moved forward and back, driving in cartridges and withdrawing shells. The outer portion of the crank-pins or journals are flattened to the circle of the periphery of the main crank for the purpose of holding the lock stationary while firing, about one-fifth part of the revolution of hand-crank, allowing time for *hang-fires*. The lock in form resembles the letter U, having an extension from its side, which contains the *firing-pin*, *main* (spiral) *spring*, *sector* or *spring-compressor*, *sector sleeve*, *extractor*, and *lock-head*. The U part of the lock that works under and around the crank-pin is curved at the inner front to correspond with the outer circle of the crank, the office of the curved front being to hold the lock in position for firing. The circular firing-pin is flattened a portion of its length near the front end, to allow it to pass under the extractor, by which it is held in position. It extends from the head of the lock through the main spring and sector sleeve, terminating in a flange or head for locking into the sear. The *sear*, having the form of a bell-crank, pivoted in the center to the lock, holds the firing-pin securely and prevents its forward motion until it is released from its hold by the action of the crank-journal when the lock is in its extreme forward position.

The sector or spring-compressor, hinged in a recess of the lock and engaging by means of gear-teeth with the sector sleeve, has its arm forced against the safety-stop as the main crank advances, thus, compressing, through the medium of the sector-sleeve, the main spring and holding it tense until released by action of the sear.

The lock-heads serve as breech-plugs, and receive the recoil when the cartridges are fired. Each lock carries a *hook extractor*, which rides over

and catches the flange of the cartridge when the lock is forced forward, and when the lock retreats withdraws the empty shell until it comes within reach of the ejector, by which it is positively thrown out. The shell-starters have a positive movement in connection with the lock-head. Should the cartridge be driven by the extractor into the barrel to its head (as is the case when the gun is worked rapidly) before the lock is in firing position, it is forced from the chamber by the shell-starter as the lock advances and is held long enough for the extractor to engage with the head, when the lock, extractor, and cartridge are driven home together.

The *ejectors*, hinged to the case, are driven by projections on the sides of the locks, which give them lateral movements to eject the empty shells, or full cartridges in case of missfires. They also serve as stops to prevent the cartridges from falling through the perforated plate as they are forced down through the feed valve.

The perforated plate extending across the rear case, to which it is fastened by a pin, has two parallel semicircular grooves, which are enlarged *extensions* of the chambers in the barrels. From the back part of the groove slots large enough to pass freely the cartridge (being wider at the rear behind the ejector than at the front) are cut downward through the plate. When the retractor has drawn the shell back nearly to the extent of the throw of the crank the ejector forces the shell through the slot, and is then in position to receive another cartridge from the feed plate or valve. The feed valve, attached to the swinging cover, has a reciprocating motion across the perforated plate. It has two angular openings of the size and shape of the outline of the cartridge, with centers equidistant with centers of the barrels. After a cartridge has dropped one-half its diameter into the valve it is forced by the action of the latter into its true position and held positively against the *cartridge support*. When the valve is again moved back the cartridge is forced downward into the perforated plate and the column of cartridges is cut off in the swinging cover feed ways, which are extensions of the *feed guide* that is located above and in line with the perforated plate.

The feed valve is driven by the *feed plate* lever. This also is attached to the swinging cover and is operated by the locks, using about one-eighth the stroke of the crank in its forward motion, thereby giving the valve time to hold both cartridge and shell down in position as they move in and out from the barrel. The *feed guide* is a simple plate, having two parallel T-grooves extending from end to end, their centers equidistant with the centers of the barrels. The upper end of the guide has a trumpet-shaped mouth, to facilitate the entrance of the cartridge heads. The lower end is provided with a cartridge stop, which lifts all cartridges contained in the guide when it is taken out from the swinging cover by which it is supported. The guide is held fast in firing position by a spring catch. It can be quickly released by drawing back the spring catch by pressure on its exposed arm. In placing the guide in position the spring catch becomes self-acting. These operations require but one hand, leaving the other free to place the safety-stop arm in position. The safety stop is an oblong block having an angular face, against which the arm of the sector in the lock may engage when the locks are moved forward by the crank. It is held in position by two links, which are moved by an arm that is pinned fast to a shaft passing through the rear case, to the outer end of which is pinned the stop-arm. This arm is constructed in the form of a hand-crank, having a stop spindle placed in its handle, behind the shoulder of which is placed a spiral spring that forces the spindle out from the

arm into the stop-holes, two in number, in the rear case. When the stop spindle is in the upper hole the *arm is in line* with barrels, the safety stop is thrown within reach of the sector arm, by which the main springs are compressed, and the gun is in firing position. When the spindle is in the lower hole the stop is carried forward out of the way of the sector arm, and in no case can the springs be compressed while the safety arm is down.

The cartridges are contained in perforated wooden blocks (holding twenty each), channeled on the sides for receiving the fitted tin covers in the manner adapted to the Gardner gun. The cartridges thus arranged are simply and readily conveyed through the feed guider to the gun, and as the block is emptied before the cartridges previously inserted are expended a continuous fire can be sustained.

In the service of the gun three men are required: one at the lever and turning the crank, one inserting and withdrawing the cartridge blocks, the other in passing cartridges properly fitted in their blocks.

Carriage.

Plates V and VI.

The distinctive feature of the carriage lies in the bed-plate, with its arrangement for oscillation, and in the manner of attaching or mounting the gun. For the latter purpose the frame fitted to the bed-plate has at its forward portion a projecting arm (x) bored at the upper end for attachment by an ordinary pinned hinge to the casing of the gun at a point just below the rear barrel rings. The second attachment is at the rear of the casing by means of a sliding clamp to the elevating (and oscillating) lever, which in its turn is attached to the plate at the point (y).

Oscillation and field of fire.

Plate V.

The bed-plate holds a spring (a, Fig. 1) by means of which the oscillation of the gun can be increased or diminished, as follows: The lug c, Fig. 5, which governs the lateral motion of the gun, has a screw attached to the upper end, this screw passing through to the rear of the bed-plate and arranged with an adjustable handle and stay-nut. When the lug is drawn by the screw to its rearmost point the lug enters the semicircular notch c, Fig. 1, and side motion of the gun is checked; as the lug is pushed forward by running in the screw, the lever being worked from side to side, it strikes the sides of the springs (a, a), the amplitude of the oscillation increasing as the lug is pushed forward, until passing the spring it reaches the circular channel k, where it is checked by a stop-pin when the gun has the full range of the horizon. When in this position the lateral motion can be checked at any point by using the clamp (Fig. 4,) encircling the rim (Fig. 1,) which, being a part of the bed-plate and attached to the carriage, is immovable.

Results of firing.

Plates I, II, and III.

Twenty cartridges, fired for the purpose, gave an average initial velocity of 1,280 feet. A test for rapidity of fire gave an average of 357 per minute.

The target firing at targets of spruce boards, 11 x 52 feet, resulted as follows:

At 200 yards, 98.20 per cent. of hits.
At 500 yards, 92.20 per cent. of hits.
At 1,000 yards, 52 per cent. of hits.

There were no missfires, and the gun worked evenly and well.

Recommendation.

The trials of this gun at Sandy Hook having shown it to be one of simple construction, easily manipulated, and of sure action (though of less rapidity of fire than other machine guns heretofore tested by the board), and in view of the fact that its cost, for a machine gun, will be comparatively light, the board would recommend the purchase by the department of a limited number for actual trial in service, as compared to other machine guns now in the hands of troops.

Nomenclature of the Gardner gun.

PLATE IV.

1. Main case.
2. Breech cover.
3. Breech cover pin.
4. Breech cover pin washer.
5. Cascabel.
6. Cascabel screw.
7. Barrels.
8. Front barrel ring.
9. Rear barrel ring.
10. Rear barrel ring pin.
11. Front barrel ring taper pin.
12. Main crank.
13. Main crank steel pieces.
14. Main crank steel pieces screws.
15. Main crank journal boxes.
17. Hand crank.
18. Hand crank handle.
19. Hand crank handle spindle.
20. Hand crank handle spindle nut.
21. Hand crank taper pin.
22. Feed valve.
23. Feed valve guide.
24. Feed valve guide screws.
25. Feed valve lever.
26. Feed valve lever slide.
27. Feed valve pivot screw.
28. Perforated plate.
29. Perforated plate taper pin.
30. Perforated plate cartridge support.
31. Perforated plate cartridge support screws.
32. Shell starters.
33. Shell starter pin.
34. Ejectors.
35. Ejector pin.
36. Lock frame.
37. Lock frame head.
38. Lock frame truck.
39. Lock frame truck pin.
40. Lock frame sectors.
41. Lock frame sector pin.
42. Lock frame sector sleeve.
43. Sear.
44. Sear pin.
45. Sear spring.
46. Sear spring pin.
47. Sector stop pin.
48. Firing pin.
49. Mainspring.
50. Extractors.
51. Extractor pin.
52. Safety stop.
53. Safety stop link.
54. Safety stop link pin.
55. Safety stop lever.
56. Safety stop shaft.
57. Safety stop shaft taper pin.
58. Safety stop arm.
59. Safety stop arm stop.
60. Safety stop arm stop head.
61. Safety stop arm stop spring.
62. Safety stop arm stop head pin.
63. Cocking cam.
64. Front sight.
65. Rear sight bar.
66. Rear sight guide.
67. Rear sight pinion.
68. Rear sight pinion head.
69. Rear sight pinion head pin.
70. Rear sight guide screws.
71. Rear sight tension spring.
72. Feed guide.
73. Feed guide catch.
74. Feed guide catch pin.
75. Feed guide catch spring.
76. Feed guide cartridge stop.
77. Feed guide cartridge stop pin.
78. Feed guide cartridge stop slide.
79. Feed guide cartridge stop slide spring.
80. Feed guide cartridge stop slide pin.

Weight of gun, 142 pounds.

Weight of gun and carriage, 502 pounds.

Special remarks.

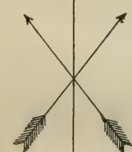
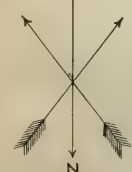
fore firing, the gun was taken ıpart by an expert; barrels beng taken off and inside mechansm taken out, and then put together again, ready for firing. Time taking apart, 1′ 2″. Time putting together, 1′ 29″. After firing the 4th series of 500 rounds, the gun was again taken apart, while hot, and after cooling the disk at and the rear end of barrels, was put together again. Time taking apart, 1′ 14″. Putting together, 1′ 43″. During the firing considerable more effort was required to work the gun when using the Frankford ammunition than when using the Bridgeport. Three men required to work gun—one to turn crank and oscillate, one to pass ammunition, and the other to feed it. The gun was not cleaned during the firing, and there were no halts or delays owing to defects of mechanism, and no failures to extract. The firing of 500 rounds for rapidity, with either cartridge, required about all the effort one man could make.

Baromet 44; re wind,

Baromet 42; re wind,

Baromet 38; re wind,

Target record of firing with caliber .45 Gardner machine gun, at Sandy Hook, N. Y., Harbor, from October 31, 1879, to January 29, 1880.

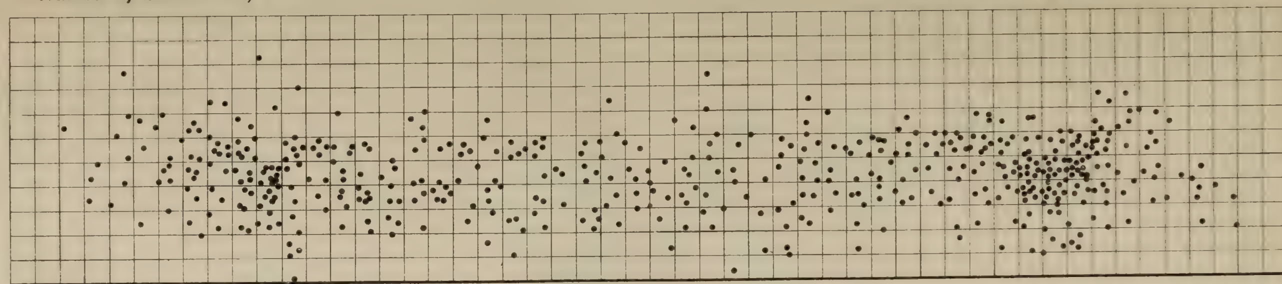
	No. of cartridges fired.	Date.	Ammunition.	Time of firing.	Initial velocity, feet.	Wind, strength, and direction.	By whom fired.	Remarks.	Special remarks.
	500	Oct. 31, 1879	Bridgeport brass shells.	1′ 22½″	....		Saunders, an expert	Fired deliberately into sand butt to test mechanism of gun.	Before firing, the gun was taken apart by an expert; barrels being taken off and inside mechanism taken out, and then put together again, ready for firing. Time taking apart, 1′ 2″. Time putting together, 1′ 29″. After firing the 4th series of 500 rounds, the gun was again taken apart, while hot, and after cooling the disk at, and the rear end of barrels, was put together again. Time taking apart, 1′ 14″. Putting together, 1′ 43″. During the firing considerable more effort was required to work the gun when using the Frankford ammunition than when using the Bridgeport. Three men required to work gun—one to turn crank and oscillate, one to pass ammunition, and the other to feed it. The gun was not cleaned during the firing, and there were no halts or delays owing to defects of mechanism, and no failures to extract. The firing of 500 rounds for rapidity, with either cartridge, required about all the effort one man could make.
	500	Oct. 31, 1879	Frankford copper shells....	....	....				
	500	Oct. 31, 1879	Bridgeport brass shells	1′ 39″	....		New hand.............	Fired into sand butt for rapidity.	
	500	Oct. 31, 1879	Frankford copper shells....	1′ 28″	....		New hand...............		
	500	Oct. 31, 1879	Bridgeport brass shells.....	1′ 17″	....		Saunders, an expert		
	100	Oct. 31, 1879	Bridgeport brass shells......	13″	....		New hand...............		
	100	Oct. 31, 1879	Bridgeport brass shells	12⅓″	....		Saunders, an expert		
	100	Oct. 31, 1879	Frankford copper shells ...	12⅓″	....		....		
Barometer, 30,347; thermometer, 44; rel. humidity, 76 per cent.; wind, 13 miles an hour.	500	Jan. 7, 1880	Bridgeport brass shells......	1′ 41″	....		....	Fired at 200-yard target. Target 11 by 52 feet, made of 1-inch spruce boards. Total number of hits in target, 491.	
Barometer, 30,256; thermometer, 42; rel. humidity, 82 per cent.; wind, 7 miles an hour.	11	Jan. 15, 1880	Bridgeport brass shells.	....	....		....	Fired at 500-yard target; sighting shots.	
	500	Jan. 15, 1880	Bridgeport brass shells......	1′ 24″	....		....	Fired at 500-yard target. Target 11 by 52 feet, made of 1-inch spruce boards. Total number of hits in target, 461. Direct hits, 447. Ricochet hits, 14.	
Barometer, 30,225; thermometer, 38; rel. humidity, 72 per cent.; wind, 3 miles an hour.	32	Jan. 16, 1880	Bridgeport brass shells......	....	....		....	Fired at 1,000-yard target; sighting shots.	
	500	Jan. 16, 1880	Bridgeport brass shells......	2′ 03″	....		....	Fired at 1,000-yard target. Target 11 by 52 feet, made of 1-inch spruce boards. Total number of hits in target, 260. Direct hits, 235. Ricochet hits, 25.	
	1	Jan. 29, 1880	Bridgeport brass shells......	....	1249		....	Fired into sand butt for velocities.	
	1	Jan. 29, 1880	Bridgeport brass shells......	....	1307		....		
	1	Jan. 29, 1880	Bridgeport brass shells......	....	1320		....		
	1	Jan. 29, 1880	Bridgeport brass shells......	....	1290		....		
	1	Jan. 29, 1880	Bridgeport brass shells	....	1306		....		
	1	Jan. 29, 1880	Bridgeport brass shells	....	1296 Average, 1296.3.		....		
	1	Jan. 29, 1880	Bridgeport brass shells	....	1303		....		
	1	Jan. 29, 1880	Bridgeport brass shells	....	1293		....		
	1	Jan. 29, 1880	Bridgeport brass shells......	....	1288		....		
	1	Jan. 29, 1880	Bridgeport brass shells......	....	1311		....		
	1	Jan. 29, 1880	Frankford copper shells ...	....	1264		....		
	1	Jan. 29, 1880	Frankford copper shells ...	....	1267		....		
	1	Jan. 29, 1880	Frankford copper shells ..	....	1257		....		
	1	Jan. 29, 1880	Frankford copper shells....	....	1266		....		
	1	Jan. 29, 1880	Frankford copper shells....	....	1258		....		
	1	Jan. 29, 1880	Frankford copper shells ...	....	1261 Average, 1264.5.		....		
	1	Jan. 29, 1880	Frankford copper shells ...	....	1275		....		
	1	Jan. 29, 1880	Frankford copper shells ...	....	1261		....		
	1	Jan. 29, 1880	Frankford copper shells....	....	1266		....		
	1	Jan. 29, 1880	Frankford copper shells ...	....	1270		....		

TARGET RECORD. 2 BARREL GARDNER BATTERY GUN, CAL. .45 INCH.

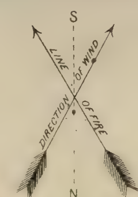
At Sandy Hook, N. J., January 7 th, 1880.

Target 200 Yards from Gun.

Number of Shots Fired, 500. *Number of Hits in Target, 491.*



Target 11 × 52 Feet. Made of 1 Inch Spruce Boards.



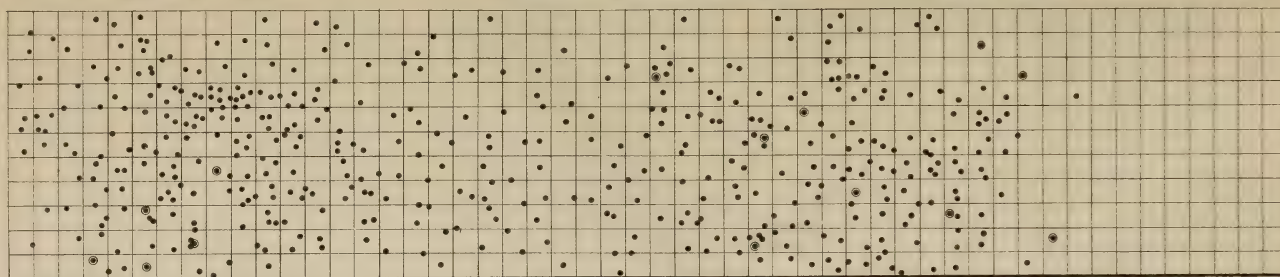
Wind, 13 Miles an Hour.

TARGET RECORD. 2 BARREL GARDNER BATTERY GUN, CAL. .45 INCH.

At Sandy Hook, N. J., January 15 th, 1880.

Target 500 Yards from Gun.

Number of Shots Fired, 500. *Number of Hits in Target, 461.* *(Direct hits, 447. Ricochet Hits, 14.)*



(Direct hits, • Ricochet Hits, ◉)

Target 11 × 52 Feet. Made of 1 Inch Spruce Boards.

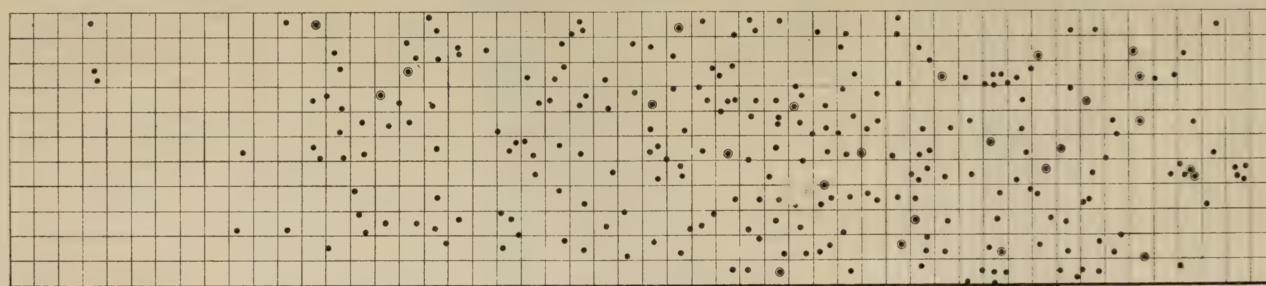
Wind, 7 Miles an Hour.

TARGET RECORD. 2 BARREL GARDNER BATTERY GUN, CAL. .45 INCH.

At Sandy Hook, N. J., January 16 th, 1880.

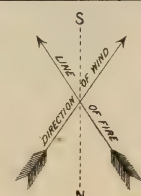
Target 1,000 Yards from Gun.

Number of Shots Fired, 500. *Number of Hits in Target, 260.* *(Direct hits, 235. Ricochet Hits, 25.)*

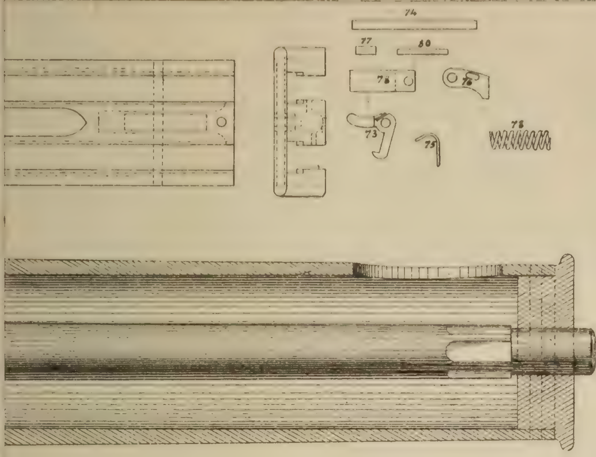


(Direct hits, • Ricochet Hits, ◉)

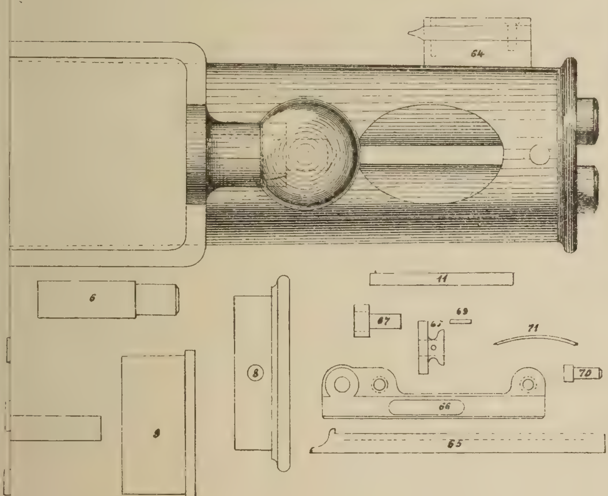
Target 11 × 52 Feet. Made of 1 Inch Spruce Boards.

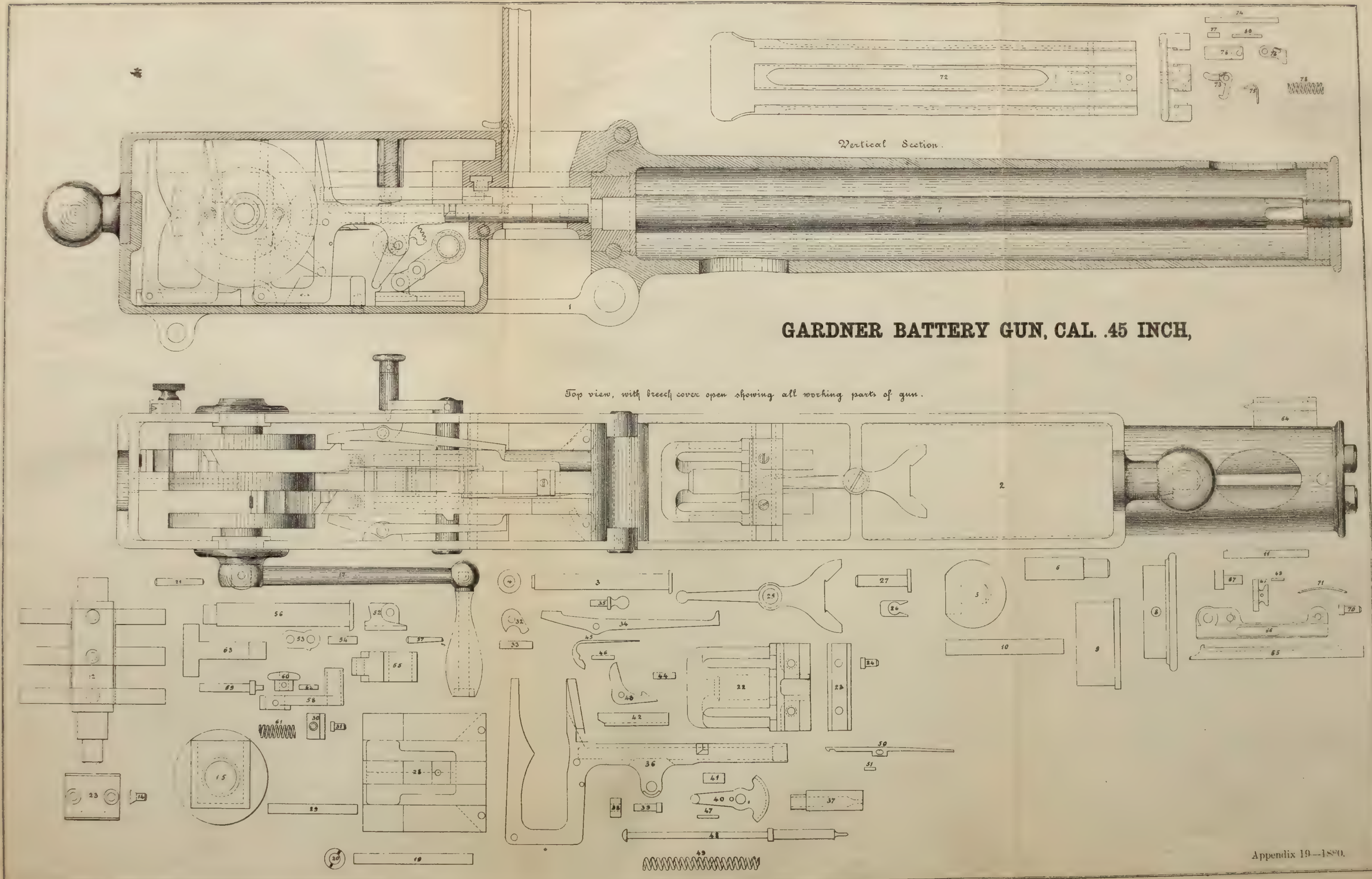


Wind, 3 Miles an Hour.

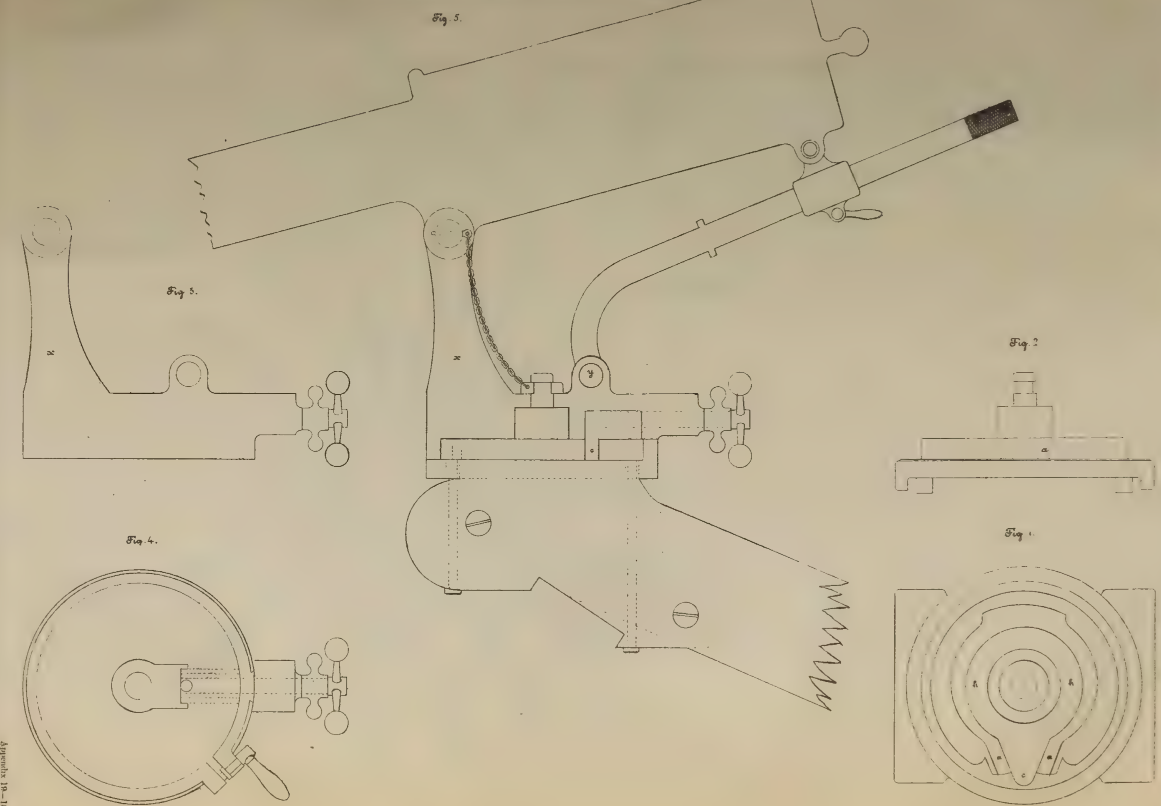


GUN, CAL. .45 INCH,



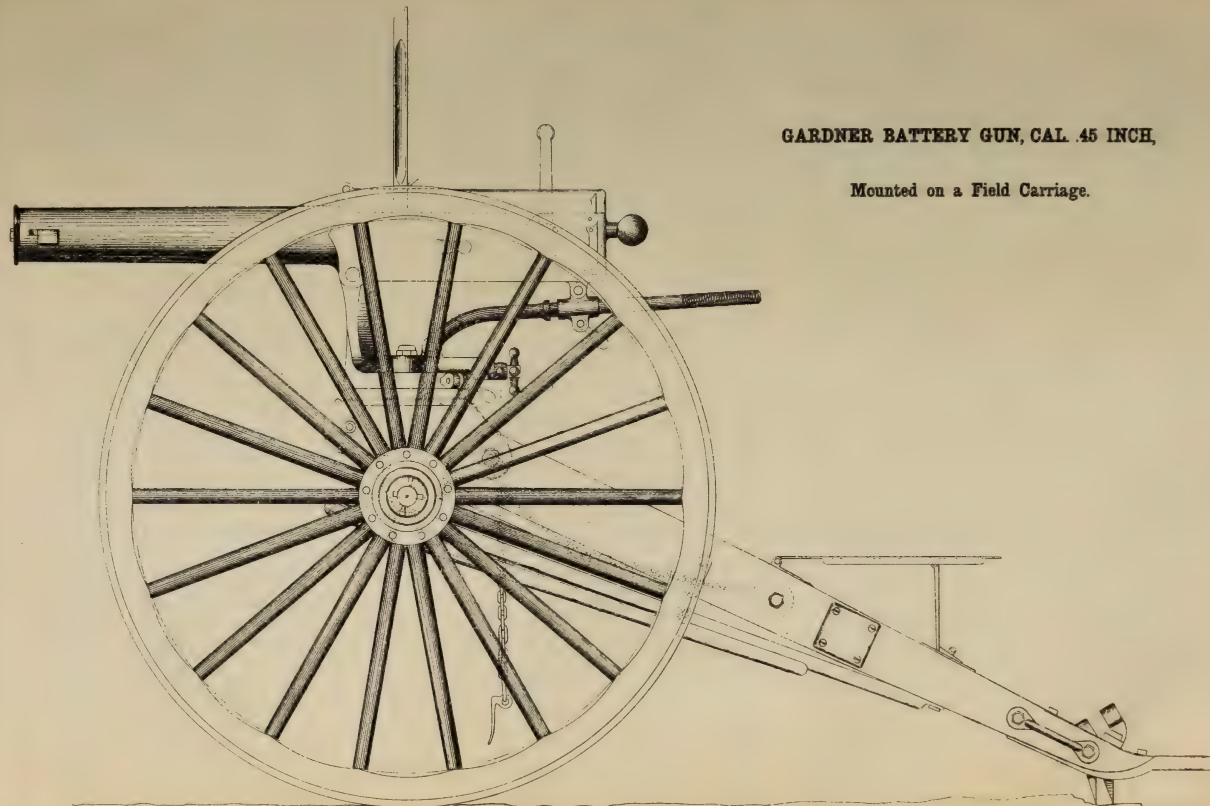

Vertical Section.
GARDNER BATTERY GUN, CAL. .45 INCH,
Top view, with breech cover open showing all working parts of gun.

GARDNER BATTERY GUN, CAL. .45 INCH.



GARDNER BATTERY GUN, CAL. .45 INCH,

Mounted on a Field Carriage.



APPENDIX 20.

GALLERY TARGET PRACTICE.

HEADQUARTERS MILITARY DIVISION OF THE PACIFIC,
DEPARTMENT OF CALIFORNIA,
Presidio of San Francisco, Cal., September 29, 1879.

[CIRCULAR.]

The following is published for the information of all concerned :

ASSISTANT ADJUTANT-GENERAL, *Military Division of the Pacific :*

SIR : The idea of using round balls and reduced charges in the service cartridge shell was suggested to me by a gentleman of San Francisco. Being satisfied of its merit after careful test, I send you herewith for trial a few cartridges loaded with 7 grains powder and round balls, caliber .44, weighing 140 grains, which, at the range of 40 or 50 feet, fired from the Springfield rifle, I have found to yield astonishingly accurate results.

They will be found, I think, very useful in lieu of indicator and candle practice, in instructing recruits ; and at reduced targets will afford the trained marksman valuable home amusement and target practice.

The bullets take the grooves perfectly, and at the ranges mentioned will just about pierce an inch board. You can try them with perfect safety in your back yard. They are made from M. L. ammunition, fabricated in 1863. Fresher powder, no doubt, in charges of five grains, would probably yield same results.

For armory practice this has an advantage over air-guns, or other guns of small caliber, because the soldier practices with his own rifle, *i. e.*, with a gun having the same weight, trigger-pull, balance, and sights, that he will be called upon to fire in actual service.

Very truly, yours,

*   *   *   *   *   *   *

The foregoing method solves practically, and satisfactorily in many respects, the question of unlimited target practice.

For this practice the targets are to be reduced directly as the ranges. For instance, if a 50-foot range be convenient, and it be desirable to obtain practice for 200, 100, and 50 yards respectively, the following method may be pursued : 50 feet being one-twelfth of 200 yards, a reduction of target to one-twelfth its size represents a target for 200 yards ; a reduction to one-sixth, a target for 100 yards ; and to one-third, a target for 50 yards. The diameter of the corresponding bull's-eyes (Creedmoor third-class target) are two-thirds of an inch, one and one-third inch, and two and two-thirds inches, respectively.

At posts where there is no obsolete ammunition of .44 calibers, molds for the spherical bullet of this size can readily be obtained from the nearest city by mail.

It is generally requisite to use with the bullet a lubricated patch in forcing it into the shell.

The shells will last indefinitely with this small charge.

By command of Major-General McDowell :

J. C. KELTON,
Lieut. Col., A. A. G.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, March 8, 1880.

COMMANDING OFFICER, *Frankford Arsenal:*

SIR: For gallery practice, the use of a very small charge of powder and a *round* bullet has given satisfaction on the Pacific coast. You will please make experiments in that direction and report the results. If successful, bullet molds to issue to troops may probably become a necessity, that they may be able to use up all their refuse lead and old bullets, &c.

Very respectfully, your obedient servant,

S. V. BENÉT,
Brig. General, Chief of Ordnance.

FRANKFORD ARSENAL,
Philadelphia, Pa., March 13, 1880.

THE CHIEF OF ORDNANCE, *Washington, D. C.:*

SIR: In compliance with your instructions in letter of 8th instant, I have experimented with round ball of varying slugging and small charges of powder, and find as follows: A slugging corresponding to a diameter of 0″.45800 as a maximum and 0″.456 as a minimum, is best. This holds the ball in position over the powder. The best charges for 50, 75, and 100 feet are, respectively, 3, 4, and 5 grains standard powder, with, say, an allowance of ½ grain for powder of varying strengths. Three samples of loaded shells, cut off to show position of ball, are forwarded, with targets made at the distances referred to—Frankford, Lowell, and Winchester. Can purchase or make some cheap bullet molds, if you desire. They will cost from $1 to $3.50, according to the number of bullets they will cast and the material they are made of—malleable iron, brass, or steel. The accuracy is little affected whether the bullets are made of lead or lead and tin. The targets were taken with Springfield rifle, caliber 0″.45, the 100-yard sight being used in aiming; weight of balls from 140 to 145 grains.

Very respectfully, your obedient servant,

JAS. M. WHITTEMORE,
Lieut. Col. of Ordnance, Commanding.

FRANKFORD ARSENAL, PA., *March* 24, 1880.

THE CHIEF OF ORDNANCE, U. S. A., *Washington, D. C.:*

SIR: In compliance with your indorsement of March 16, 1880, Bureau No. 866A, I have the honor to submit such suggestions as experiment has shown of practical value in the use of round balls, small charges of powder, and reloading shells for gallery rifle practice.

The balls should be of sufficient diameter to slug in the rifling of the bore, and fit closely over the powder in the bottom of the shell. Any motion of the ball in the shell would vary the position the powder takes when poured in, and gives uncertain shooting. There is less fouling of the gun barrel when the balls are slightly lubricated with Japan wax, paraffine, or some lubricant that solidifies in cooling, as distinguished from oils that remain liquid. Good results were obtained by melting Japan wax, immersing the balls in it, and shaking off the excess of the lubricant in a sieve. In firing 100 rounds with ball lubricated, the weight of fouling was 50 grains, without lubricant 150 grains. When no lubricant

is at hand, wiping out the bore after every 5 or 10 rounds, and then running a slightly oiled rag through it, will answer. The firing is more accurate when the shells and gun are cleaned after every 5 or 10 rounds; the shells washed in warm water, and the bore of the gun wiped out by pushing a wet rag through it, and afterwards an oiled one.

The endurance of the Frankford, Lowell, and Winchester shells is from 200 to 300 rounds fired with round balls and small charges. They give out by the bottom of the pockets getting knocked in by repeated blows of firing-pin, which causes the primers to miss fire. When short of shells, the expedient could be resorted to of putting a thin disk of metal in the bottom of the pocket, with a vent-hole in the middle, until the bottom of the pocket is entirely knocked through.

Charges of 3, 4, and 5 grains of Oriental standard musket powder gave good accuracy at 50, 75, and 100 feet, respectively, firing from a shoulder and muzzle rest. A wooden drift, with shoulder to prevent the ball from being driven in too tightly, is convenient. When any shell becomes expanded so as to fit chamber of gun tightly, it can be resized in the resizing die accompanying the reloading tools. This will not often happen.

Bullet molds made with a little care, and warmed up by pouring a ladle full of melted lead in and over the mold before casting the balls, will insure them of sufficiently uniform size to do good shooting.

The penetration of round ball with 5 grains powder at 50 feet is about 1 inch in white pine, and slightly more in hemlock. A board from 2 to 4 inches thick is soon cut through by the balls. A box or barrel filled with dirt and placed in rear of target will catch the spent lead and prevent injury to the gallery. A butt made larger and filled with earth or sand will afford a better protection. If the balls are fired into and lodged in thick wood, difficulty will be experienced in digging them out. An iron screen would cause the balls to splash and rebound about the target, hence earth would seem to be best to fire into.

The above gives some idea as to what should be done to prevent the gallery from being defaced and persons being injured standing near the target for scoring shots.

A pound of powder furnishes 1,400 5-grain charges, a pound of lead 50 balls. The lead can be recast as long as it lasts, taking care that it is not burned in remelting. Fifty shells will answer for 10,000 rounds at 200 rounds each, requiring 10,000 primers for reloading. With 50 men to a company, 10,000 primers, 50 shells, 40 pounds of lead, and 7 pounds of powder will give 200 rounds per man, assuming that the balls can be remelted and recast 4 times before the lead is entirely consumed. Friction in shooting wears away the lead.

As the lead and tin of rifle bullets answers equally well with lead alone, rifle bullets recovered can be recast into round balls. The penetration of the rifle bullet into sand and earth is as follows: Into compressed loam, 9 to 16 inches; into loose sand, 5 to 9 inches; box 2 feet square, white pine $\frac{5}{8}$ inch thick, filled with loose earth, penetration 18 to 24 inches; box filled with sand, penetration 9 to 18 inches; range 50 yards; which indicates how the butt should be made to catch the spent bullets in rifle practice.

Appurtenances required for melting lead, recasting bullets, reloading, &c. These prices are approximate:

7-inch melting ladle	$0 75
2-inch pouring ladle	25
Bullet molds to cast 4 bullets	3 00
Brass charger, adjustable to 3, 4, and 5 grains, by the hundred	15
	4 15

Targets like inclosed sample can be printed cheaply here, and issued, if thought necessary.

This is for 75 feet, and might answer as a mean for the three distances, 50, 75, and 100 feet. The wooden drift for punching cartridges from reloading die and mallet for driving bullets home into shells, accompanying reloading tools, will answer for setting the bullets down over the powder in the shells.

My experiments, made here in 1879, indicated that with 10-grain charges and longer ranges than 100 feet the pistol bullet with flat base gave more accurate shooting than round ball of equal diameter with equal charge. As the round ball is lighter than the pistol bullet of equal diameter its initial velocity is greater with equal charges, and for distances not exceeding 100 feet the loss of velocity in reaching the target is so small that with the slugging of the ball in the rifling of the bore it shoots very accurately. With an increase of range this accuracy would fall off, and the heavier conical bullet with larger charge would be required for good practice.

For the information of those interested in out-door shooting it may be well to state that with 10 grains of powder and wad on top to keep the charge from rolling into cavity of pistol bullet, excellent shooting can be had at from 200 to 300 feet with that bullet either in rifle or carbine.

Very respectfully, your obedient servant,

JAS. M. WHITTEMORE,
Lieut. Col. of Ordnance, Commanding.

HEADQUARTERS MILITARY DIVISION OF THE PACIFIC,
DEPARTMENT OF CALIFORNIA,
Presidio of San Francisco, April 8, 1880.

Respectfully returned to the Chief of Ordnance, U. S. A.

It is observed the conclusions arrived at by Lieutenant-Colonel Whittemore in respect to the method of practicing with reduced charges and round balls are quite in accord with those developed here. I am sure, however, that powder issued to companies will not in 3, 4, and 5 grain powder charges give the results Colonel Whittemore obtained from these quantities of Oriental standard. I suggest, therefore, the graduated powder charges be prepared to measure 7 and 10 grains, and that the charges be limited to those quantities for the ranges of 50 and 70 feet, respectively, as those are the *fine-sight*, "point-blank" distances for 7 to 10-grain charges of the ordinary government powder, and 70 feet is the limit at which the average eye can see clearly the shot-mark.

This is important, for with the reduced target the firer should know exactly where his shot strikes. Then, too, this is about the extreme range at which a man can conveniently act as his own marker. I think the butts should be faced with iron or lead, as may be found expedient. The slab of lead can be run from spherical projectiles, caliber .45, which have been fired. The iron target, when no thin boiler plate can be obtained, may be improvised readily out of material at every post. Whether iron or lead targets are used, paper targets become unnecessary.

I suggest sufficient lead and primers be allowed to give each man 300 rounds per year. With the ordnance powder issued to companies this year the penetration of red wood, a very soft fir, with 7 grains is not quite $\frac{3}{4}$ of an inch; 10 grains gives a penetration of $1\frac{3}{8}$ inch. Lubricating the ball is very important. By the Boutelle method the tallow fastens the ball in the shell without coming in contact with the powder, to its injury. This lubricant is, moreover, most easily obtained.

J. C. KELTON,
Lieut. Col. and A. A. G.

FRANKFORD ARSENAL PA., *April* 21, 1880.

Respectfully returned to the Chief of Ordnance, U. S. A.

I can make a small charger to gauge 7 and 10 grains as economically as one to measure 3 and 5 grains. Assuming 50 men to a company and 300 rounds per man, 75 shells, 60 pounds lead, and 14 pounds powder would be required, according to my estimate, for 200 rounds per man. To insure a sufficient supply it might be well to issue 100 shells, 100 pounds lead, and 25 pounds powder to each company of 50 men.

JAS. M. WHITTEMORE,
Lieut. Col. of Ordnance, Commanding.

ORDNANCE OFFICE *April* 22, 1880.

Respectfully returned to commanding officer Frankford Arsenal.

I see no use of issuing shells specially. Can't the ordinary shell of the service cartridge be used with round bullet? If it cannot, then one-half the merit of the idea is lost and we must look for something better. Please be more explicit.

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

FRANKFORD ARSENAL, PA., *April* 23, 1880.

Respectfully returned to the Chief of Ordnance, U. S. A.

Any of the reloading shells will answer, "Frankford," "Winchester," "Lowell," or "Berdan." The latter, with its folded head and cup inside the shell, is not so well adapted for the purpose as the first three. The number enumerated was to give you an idea as to what would be required in providing for gallery practice. I assume that by "service" you mean any of the reloading shells used in the service, as it would cost from 200 to 300 times as much to use the service cup and shell, to be thrown away after firing one round.

JAS. M. WHITTEMORE,
Lieut. Col. of Ordnance, Commanding.

HEADQUARTERS MILITARY DIVISION OF THE PACIFIC,
DEPARTMENT OF CALIFORNIA,
Presidio of San Francisco, Cal., March 8, 1880.

To the CHIEF OF ORDNANCE, U. S. A., *Washington, D. C.*

SIR: I have the honor to state, in reply to your communication of February 11, 1880, that reports were called for from all companies in the Department of California as to the advantages gained in marksmanship by the use of round balls fired with reduced charges at short range. I have received replies, and regret to say but two companies in the department have attempted any practice with reduced charges and round balls. Some company commanders claim "that not having any obsolete bullets caliber .44," others because "their requisitions for bullet molds were not filled" they did not have the means of practicing. Most company commanders have not given any reason for not trying this method of target practice. I can therefore only give the result of the practice of the two companies referred to and the experience of myself and two other officers at this station.

The bullets used by these companies and by the officers referred to were purchased in the market, were dropped bullets and therefore not perfect spheres. But, nevertheless, the practice at short range does not

appear to have suffered from that cause. With 7 grains of ordnance powder, 1878, covered with a lubricated wad and the dropped ball also covered with a wad, at 50 feet, the "point blank" of that charge, firing at a target the bull's eye and circle of which were $\frac{1}{12}$ of the Creedmoor 200-yard target, individual practice of some excellent shots was not at first so good as with full charges at 200 yards range. This was doubtless due to the fact that the rifle with the 7-grain charge was not held steadily on the object after firing, for with this small charge the ball travels with so slow velocity it is an appreciable time in passing through the barrel, during which, without great steadiness, sufficient motion is apt to be given to the barrel to divert it. But it is that very fact, that the rifle must be kept on the object after firing, which renders this kind of practice so valuable. The firer soon discovers this, and then his practice at once improves. The habit he acquires in this respect in short-range aiming he carries into long-range practice with results as gratifying as they are astonishing.

With 7 grains of powder the report of the rifle is not so loud as the report of a percussion cap, the powder is nearly all consumed or condensed in the barrel and consequently there is little smoke; the practice can therefore be carried on anywhere, even in the squad-room. The reduced charge fouls the rifle much more than the full charge. With the 7-grain charge the ball is just buried in the soft pine. One great source of interest in this practice is that the firer sees instantly the point of impact of his ball, even while holding his rifle on the object, and can therefore readily see his error and remedy it. This and the absence of recoil causes improvement in the firing of beginners to commence at once. At 70 feet, with a target $\frac{1}{8}$.5 of the Creedmoor 200-yard target, the "point-blank" charge is 10 grains. Practice with this charge is altogether the most interesting, though not so instructive as at the shorter range with the smaller charge. The impact of the bullet can still be seen, while the increased charge gives a velocity to the ball which carries it clear of the rifle too quickly to be diverted by any motion communicated to the rifle after the cartridge is fired.

What has been done in other departments in this practice is not known. Since orders now confine target-practice information to department headquarters, the division headquarters has no knowledge of what is being effected in this matter in the Departments of the Columbia and Arizona. The battery of light artillery at this post is armed with carbines, but has never had any practice till within a few weeks. They now practice under the instructions of Lieutenant Anderson, F, Artillery, a Creedmoor shot and one of the best riflemen in the army. The battery commenced firing at 100 yards with full charges. Finding the firing wild and no improvement after some days, the men were given round-ball cartridges with reduced charges. After some days of this practice they resumed the full charge, firing at 100 yards. Those who at first had only been able to score 8 and 12 per cent. had improved their score to 60 per cent.

It is hoped you will be so convinced of the usefulness of this small-charge practice that you will approve a limited issue of round balls, caliber .44, better .45, with or without lubricated wads, or the issue of bullets molded, caliber .45, to each five men of the companies serving in this division.

All company commanders will then, or can be compelled to, try reduced-cartridge practice, certainly to the great improvement in their long-range practice. I inclose you the reports of the company commanders referred to in the foregoing part of this communication.

The accompanying interesting report was received this morning from

Lieut. F. A. Boutelle, First Cavalry, a "Creedmoor man," now stationed at Camp Howard, Idaho Territory.

Very respectfully, your obedient servant,

J. C. KELTON,
Lieut. Col. and A. A. G.

FRANKFORD ARSENAL, *March* 25, 1880.

Respectfully returned to the Chief of Ordnance.

Targets can be printed proportioned as Colonel Kelton specified, if desired, instead of a 75-foot range target taken as a mean, as I have suggested. Lieutenant Boutelle's target of wood, 2 inches thick, 2 feet square, and faced with 3-16-lb. boiler iron, is a good one when the materials are at hand. An ammunition box filled with sand and proper targets pasted on would also answer. Lubricating the ball in the shell by letting melted tallow drop upon its exposed surface is a happy thought, but may consume more lubricant than is necessary. With the balls fitting the shells snugly, as they will, cast in the molds to be furnished, no wads are necessary. They can be improvised when required with loose balls. In my report I did not describe any particular kind of butt or target, as the means at hand will determine those points.

JAS. M. WHITTEMORE,
Lieut. Col. of Ordnance, Commanding.

P. S. General Perine informs me that a slab of lead one foot square and one inch thick has given better satisfaction for stopping the balls and saving the lead than any other method. At many posts the lead can be obtained and cast into a slab.

J. M. W.

PRESIDIO OF SAN FRANCISCO, *March* 5, 1880.

To the ASST. ADJT. GENL., M. D. P. AND D. C.,
Presidio of San Francisco, Cal.:

SIR: In reply to your communication of the 3d instant, I have the honor to report that, in my opinion, by the use of the round ball with reduced charges in the service rifle the recruit may more readily than otherwise be taught to hold his gun with steadiness, pull trigger without deranging his aim, and overcome a very natural tendency to shut his eyes and shrink from the recoil of his piece at the moment of its discharge, while the trained soldier may thereby conveniently and economically preserve and improve that accord between the brain and the muscles without which the best marksmanship is impossible.

After the introduction of this method of instruction, men of my company were improved who had for many months, under careful coaching, failed to make respectable scores. In this connection I would respectfully refer the division commander to later target records of my company. In preparing reduced cartridges, to secure the best results care is necessary, not only in proportioning the charge to the powder and range used, but in loading the same. The bullets should be *true*, and on this account the *molded* are better than the dropped; they should fit *snugly* at the bottom of the service shell, otherwise a lubricated patch should always be employed. With *very* small charges it is well to have a stiff wad between the powder and bullet. When the bullet is well home the miss-fires are fewer and the shooting is more accurate than when there is an air-space between the powder and the bullet.

Very respectfully,

FRANK G. SMITH,
Capt., First Artillery, Commanding Co. H.

HEADQUARTERS MILITARY DIVISION OF THE PACIFIC,
DEPARTMENT OF CALIFORNIA,
Presidio of San Francisco, Cal., March 8, 1880.

Capt. FRANK G. SMITH,
Commanding Co. H, Fourth Artillery,
Presidio of San Francisco, Cal.:

SIR: In your report upon round-ball firing with reduced charges, you invite attention to the improvement effected in your company by this kind of practice. I find your company's percentage in July and August last to be 62, but am at a loss to determine what it is by your last return. Please state what is the relative improvement.

Very respectfully, your obedient servant,

J. C. KELTON,
Lieut. Col., A. A. General.

PRESIDIO OF SAN FRANCISCO, *March* 10, 1880.

Respectfully returned.

Where many measures are simultaneously in operation to improve the shooting of a company it is difficult to determine the amount of improvement due to each; but after having placed cartridges with reduced charges in the hands of my best shots, I was satisfied that good shooting might be done with them. Afterward the shooting of the worst shots was much improved thereby. Although practice with reduced charges has not been pursued as systematically as I could wish, I am satisfied that this method deserves all the attention it could receive. I attribute the high percentage of possible scores attained by my company in November and December, 1879, at 100 yards, largely to this; also, the marked improvement observed among my worst shots. Pat. Woods, who during the past year or eighteen months has almost invariably been reported as my worst shot, during the month of February scored 76 per cent. at 100 yards.

FRANK G. SMITH,
Capt., Fourth Artillery, Commanding Co. H.

CAMP HOWARD, IDAHO, *February* 11, 1880.

The CHIEF OF ORDNANCE, *Washington, D. C.:*

SIR: Acting upon a suggestion made in a circular from Headquarters Military Division of the Pacific, I have been practicing in doors with the Springfield rifle with round bullets and reduced charge of powder with so good results that I have thought the subject worthy of a special report, and with it the suggestion that, as the material costs very little, the furnishing the army with a supply of round bullets. The first targets used were wooden, but the light charge used was not strong enough to penetrate the wood, and the bullets rebounded very unpleasantly. Finding a piece of 3-16 boiler iron at the post, I had constructed a wood target (butt) 2 feet square and 2 inches thick, faced with the iron. On this the bullets flattened and fell to the ground without any rebound or splash. The target is painted white, and the true dimensions of the target scratched thereon with a pair of carpenter's dividers. For the bull's eye the paint is scraped off. In practice the shot marks are painted out. I have used 6 grains Hazard's electric powder and round bullets purchased at a neighboring village. When I first commenced practice the target seemed very small, and I was unable to make good scores, but after five or six days' shooting I made the target inclosed. I have experimented with the bullets both patched and lubricated, and find better results with the latter. I seat the bullet on the powder with

a wooden rammer, and lubricate with tallow melted and dropped from an oil-can on the face of the bullet in the shell; the tallow runs from the face around the sides of the shell and cools almost immediately. It is believed to be well known and fully appreciated that range practice, when the weather is unfavorable, is of little benefit, and might quite as well be omitted. With the round bullets practice can be constant, as almost all company barracks have a sufficient dimension. They would also be particularly advantageous in instructing recruits in quarters, where the groundwork for a good marksman is laid.

If the round bullets cannot well be furnished, it is recommended that each company be supplied with a mold in which more than one bullet can be molded at a time; also a large supply of primers. In the company to which I am attached (D, First Cavalry, Captain Forse) round bullets are molded, but the mold only casts one, and the operation of making bullets in that way is very slow. The round bullet is only recommended to be furnished in place of the conical for in-door practice, on account of its lesser cost and the necessity for adaptability of light targets.

Very respectfully, your obedient servant,

F. A. BOUTELLE,
First Lieut., First Cavalry, Commanding Post.

FORT POINT, CAL., *March* 4, 1880.

The Adjutant General, Military Division of the Pacific, and Department of California:

SIR: In reply to your letter respecting rifle-practice firing with reduced charges of powder, I have the honor to state that for the first two months my company (K, Fourth Artillery), in addition to the ordinary practice, has used a reduced target with round ball and seven grains of powder. This charge gives satisfactory results for fifty-feet range. The practice has been voluntary. I find the men take a great interest in it. If a small allowance of powder and bullets were issued specially for this practice, as much benefit would be obtained as from an ordinary shooting-gallery.

Very respectfully, your obedient servant,

JOHN EAGAN,
Capt. 4th Art'y, Com'd'g Co. K, 4th Art'y.

ORDNANCE OFFICE, WAR DEPARTMENT,
Washington, July 13, 1880.

The COMMANDING OFFICER,
Frankford Arsenal:

SIR: You will please manufacture for gallery practice the following articles, viz: 500,000 lubricated round balls, cal. .45; 200 adjustable brass chargers for 7 and 10 grains powder. Also purchase for same purpose: 100 7-inch iron ladles for melting lead; 100 2-inch iron ladles for pouring lead; 100 25-pound cans, such as are used by powder manufacturers; 100 tin strainers. The strainers are for dipping out balls from melted lubricant. Their size and shape should be such as to hold from 10 to 20 balls, with handle to shake off surplus lubricant.

When the above stores are ready, report; also the method adopted for making the balls by the quantity.

Respectfully, your obedient servant,

S. V. BENÉT,
Brig. Gen., Chief of Ordnance.

[First indorsement.]

FRANKFORD ARSENAL, PA.,
September 29th, 1880.

Respectfully returned to the Chief of Ordnance, U. S. A.

There have been manufactured at this arsenal in accordance with the within instructions 500,000 lubricated round balls, cal. .45, packed in boxes of 2,000 each, at a cost of $1.71 per thousand. Two hundred brass chargers, graduated 7 to 10 grains, as devised by Captain Metcalfe, at a cost of 19 cents each. There have been purchased 100 7-inch wrought-iron ladles, at 65 cents each; 100 2½-inch wrought-iron ladles, at 17 cents each; 100 25 pound tin powder-cans, at 36 cents each. The ladles were obtained by contract, and 5 cents should be added to the cost of each, that being the cost of advertising for, and preparing the contract, and other clerical work connected therewith. Two and one-half inch ladles were procured instead of 2-inch, the latter not being a trade manufacture, and the former not too large for the purpose for which it is intended.

The stores are ready for shipment and await the orders of the Chief of Ordnance. The operations for the manufacture of round balls, cal. .45, are as follows: Casting, tumbling, lubricating, packing.

Casting.—For this purpose a mold is employed capable of casting 20 balls at once. One-half the mold is brought up to and moved away from the other half, keeping parallel to it, by a screw passing through the side of the frame containing the whole apparatus. This arrangement is necessary on account of the tendency to spring open in the middle which would result from the use of an ordinary pivoted mold. In other particulars, except in size, this mold resembles those ordinarily used for this purpose. It requires the same precautions against running the metal either too hot or too cold, precautions which can only well be learned by experience.

The service alloy of 16 lead 1 tin is employed. It is ladled frequently from one pot to another and carefully stirred and skimmed to keep it homogeneous.

A short, square hook to pull out the sprue-head from the shears, a bronze hammer to drive the shear in cutting off, and a wooden mallet with which to rap the balls from the open mold are required. The mold is fastened to a stout table, through which the balls fall when released into an open box. Their fall is broken by a leather apron.

The product of the mold is frequently gauged by trying the balls in maximum and minimum holes, respectively 0.459 and 0.454 in diameter, to guard against wear. A man can cast in a day of ten hours about 10,000 bullets, besides keeping up his fires and pots, &c.

Tumbling.—In order to remove the sprue-head, unavoidably left by the casting, the balls are tumbled. This operation consists in placing about 5,000 balls with about a bucket of water in a cylinder inclined at 45° and making about 40 revolutions per minute. They are left there for half an hour and then removed and dried, preferably in the sun. The water is required to break the force with which the bullets strike each other in rolling. Without it, the effect of the tumbling is to perceptibly increase their size owing to the numerous small dents raised on their surfaces. One man can tumble about 100,000 balls per day of 10 hours.

Lubricating.—When dry the bullets are lubricated. About 10 or 12 pounds of bullets at a time are placed in a wire basket and dipped for a moment into a vessel containing melted Japan wax, at about 160° to 170° Fahr. They are then poured out upon a board about 5 feet long, the upper end raised about 2 feet and the lower end leading into a bucket

of cold water into which the bullets roll. The board has strips on its sides, forming a shallow rectangular gutter. The balls are poured from the strainer upon a piece of coarse wire netting, ¼-inch mesh, through which the surplus wax falls into a box. The balls are preferably poured *up* the board, as in so doing they start down together and the wax is more uniformly distributed. The balls should not be dipped too long in the melted wax or they will scatter it all off in their descent; nor should the descent be too short, or the wax will be lumpy or too thick. A little care and experience regulate these points, the object being to get a tough, thin, and even coating of the wax. The bucket is emptied from time to time and the balls spread in trays with wire bottoms for drying. The floating wax is removed and dried for remelting, and the gutter occasionally scraped. A man can lubricate, working continuously, in a day of ten hours, 100,000 balls.

Packing.—The packing-box is made of ⅞ stuff, like the service cartridge-box. It is made of the following dimensions inside, 12″.94 x 9″.25 x 2″.5 deep, and is designed to hold 2,000 balls, these being packed in five layers of 20 x 20 balls each. The manner of packing gave some trouble till the following ingenious plan was determined. It was found that the bullets when thrown in loosely, as by weight, would not assume their smallest compass until after protracted shaking, as in severe wagon transportation. This would leave a vacant space, causing further rattling and wearing and melting of the lubricant from the heat so engendered. Even when placed in layers separated by flat sheets of strawboard, owing to the natural tendency of round balls to form in rings until settled by shaking, the box could never be packed full, and as in the former case these rings would coalesce, leaving vacant spaces into which the weight above would press, bending up the strawboard and destroying the whole arrangement.

The plan now followed was then devised by Captain Metcalfe, who has had sole charge of the manufacture of the balls, their lubricating and packing. It consists of placing the balls in layers between sheets of corrugated strawboard. The corrugations being such as would just receive the balls in separate rows, and so forming gutters which could be easily filled by slightly elevating one side of the box containing them and pouring in the balls loosely by hand *upwards*, as in lubricating. Each row could thus be *absolutely* counted and filled, and so each layer, and so the box, after which motion of the contents became impossible. The top layer being covered with a layer of strawboard, this was covered with a wisp of tow on which the lid was drawn tightly by the screws. Prolonged trial of this arrangement on the jiggler specially contrived to resemble prolonged transportation of the roughest kind failed to disturb it in the least.

The packing was easily made by running strips of No. 60 strawboard 9″.25 wide through wooden rolls 2″.34 in diameter, 9″.5 long and cut with 15 longitudinal grooves 0″.36 deep and meeting at an angle of 60°. The rolls were made of hickory, which lasted very well. The rolls were mounted on an ordinary engine lathe running at 860 revolutions per minute. The upper roll was driven by the lathe directly and meshed into the lower roll which lay in wooden bearings cut in a temporary frame resting upon the ways of the lathe. One side of this frame formed a guide to keep the sheets square to the rolls. The strawboard was fed over a wooden guard to protect the operator from accident.

The strips were cut extra long to allow for trimming by hand in packing. They could not be cut to exact length beforehand owing to the impossibility of always striking the rolls at the same place in corrugat-

ing. Two boys, one to feed the rolls and one to take, can corrugate in one day of ten hours 5,000 sheets of packing.

NOTE.—The present size of No. 60 strawboard, viz, 26 x 37, does not cut to advantage for corrugation. If ever used in large quantities for this purpose it should be 30 x 38, making 8 sheets each.

To complete the half rows occurring at alternate ends of each layer, each box requires five wooden sticks 0''.3 x 9''.0.

One man will saw in one day of ten hours about 3,000 of these sticks, though by special appliances this number may be largely increased.

The cost of the manufacture of these balls is shown by the following table:

Labor		$149 40
Add 25 per cent. for shop expenses, &c		37 35
		186 75
Materials:		
9,400 pounds lead, at 5 cents	$470 00	
600 pounds tin, at 20 cents	120 00	
150 pounds Japan wax, at 17 cents	25 50	
2,500 pounds coal, at $6 per ton	6 70	
329 pounds strawboard, at 3½ cents	11 51	
1,000 feet box-lumber	27 50	
7 gross screws, at 40 cents	2 80	
80 pounds nails, at 4 cents	3 20	
		667 21
500,000 balls, at $1.71 per M		853 96

The methods have been described so as to make their repetition on either a large or a small scale easy.

A small box containing 1,000 balls, showing through a glass plate the cellular method of packing, is submitted herewith.

S. C. LYFORD,
Major of Ordnance, Commanding.

APPENDIX 21.

BENTON'S ELECTRO-BALLISTIC MACHINE FOR DETERMINING THE VELOCITY OF PROJECTILES.

Description prepared under the direction of Col. James G. Benton (the inventor), commanding the National Armory.

BY CAPT. JOHN E. GREER, ORDNANCE DEPARTMENT.

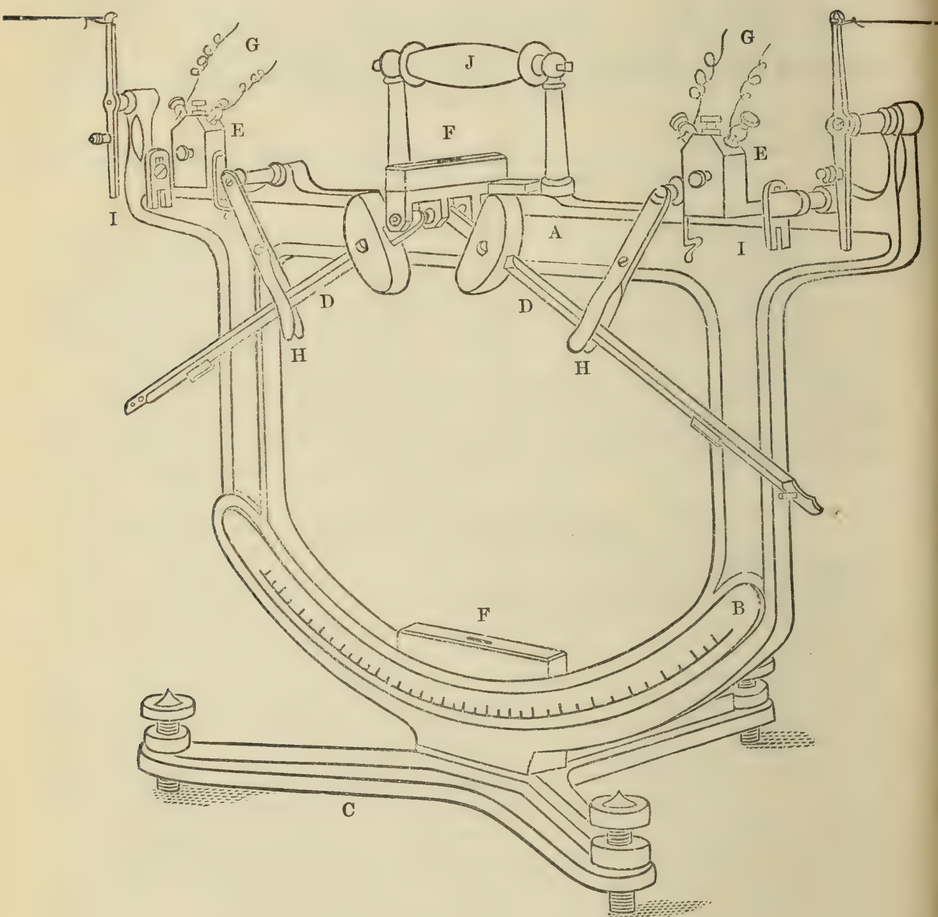
The Electric Velocimeter, invented by Col. J. G. Benton, Ordnance Department, United States Army, and generally known as the West Point or Electro-Ballistic Machine, is shown in the accompanying engraving.

This machine, first brought to notice in 1859, is described in Colonel Benton's "Ordnance and Gunnery," pages 390–395. During late years, however, the improvements have been so varied as to render a new description desirable. The following has, therefore, been prepared:

DESCRIPTION OF MACHINE.

This machine as now constructed consists of an upright limb, A, carrying a graduated arc, B; a triangular support, C, to which the limb is secured by screws; two pendulums, D D, having a common axis at right angles to the plane of the arc and passing through its center; and two electro-magnets, E E, attached to the horizontal limb of the arc, which serve to hold up the pendulums when they are deflected through an angle of 90° from the zero of the scale. By means of two spirit-levels, F F, at right angles to each other—one above and parallel to the axis about which the pendulums revolve, the other in the plane of the arc at its lowest point—and leveling screws at the extremities of the triangular support, the arc may be brought into a vertical plane. The magnets, of the purest attainable soft iron, are of the horse-shoe form, and are very compact, those more recently constructed not exceeding an inch and a half in height, an inch in width, and half an inch in thickness. By means of screws, G G, working in collars at the top of the cases inclosing the magnets, the latter may be raised or lowered for the purpose of adjusting the machine, as explained further on. At the lower extremity of the inner pendulum is pivoted a delicate bent lever, the end of which next the arc terminates in a fine point, which is lightly covered with printer's ink. At the lower extremity of the outer pendulum is a conical-shaped rod, which, striking the outer end of the bent lever, rotates the latter so as to press the point against the arc, leaving a dot of ink, which marks the point of passage of the two pendulums when they fall by reason of the breaking of the electric currents which excite the magnets. Two forked springs, H H, catch the two pendulumss as they rise the opposite sides of the arc and prevent unnecessary wear of

the journals; the latter turn in hardened steel bearings. Two stops, I I, also fork-shaped, are so adjusted as to cause the pendulums to be at 90° from the zero of the scale when held suspended by the magnets. A handle, J, above the limb enables the machine to be carried from point to point.



THEORY OF THE MACHINE.

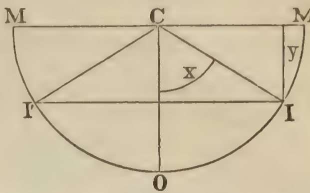
As an origin of reference the zero at the lowest point of the scale is taken. When the machine is properly adjusted the place of meeting of the pendulums when simultaneously released should be at this point.

The velocity of the electric currents being considered instantaneous, and the loss of power of the magnets simultaneous with the rupture of the currents, it follows that each pendulum begins to move at the instant the wire leading to the magnet sustaining that pendulum is cut, and that the interval of time between the cutting of the wires corres-

ponds to the difference of the arcs described by the pendulums up to the time of meeting.

Let M and M′, Fig. 1, represent the positions of the two magnets, and let the interval between the rupture be such that the centers of oscillation will pass each other at I. As the times of vibration are equal, the interval of time will correspond to the arc I I′, the arc M′ I being equal to M I′. A vertical line through the center of motion bisects the arc I I′. The reading, therefore, corresponds to one-half of the required time, or time of passage of the projectile between the wires.

Fig. 1.



To determine a formula for the time that it takes for one of the pendulums to pass over a given arc, let l be the length of the equivalent simple pendulum; v the velocity of center of oscillation or point M′; y the vertical distance passed over by this point; x the variable angle which the axis of the pendulum makes with the vertical; and t' the time necessary for the point M′ to pass over an entire circumference, the radius of which is l, with a uniform velocity, v. We then have:

$$v = \sqrt{2gy}.$$

Substituting for y its value in terms of x, the above expression becomes:

$$v = \sqrt{2gl\cos X};$$

from which it is evident that the velocity of the pendulum increases from its highest to its lowest point.

The time t' is equal to the circumference of the circle, the radius of which is l, divided by the velocity v; if this value of t' be again divided by 360, we shall have the time of passing over each degree, or—

$$t = \frac{2\pi l}{360\sqrt{2gl\cos X}}.$$

Calling l' the length of the seconds pendulum, and t'' the time of a single vibration of the pendulum of the machine, we have by known laws, $l = l'\,t''^2$ and $g = \pi^2\,l'$. Substituting these values in the value above given, and representing—

$$\frac{t''}{180\sqrt{2}} \text{ by } a, \text{ we have}$$

$$t = \frac{a}{\sqrt{\cos X}}.$$

To determine t'' the pendulums are removed from the machine, and the cylindrical journals about which they revolve are replaced with others, the bearing surfaces of which are knife-edges. Each pendulum is started, vibrating through a very small arc. By means of a stopwatch the time of 1,000 vibrations may be found. By repeating the operation several times and taking the mean, the time of a single vibration may be determined very exactly. This time for pendulums of recent construction is 0.378 of a second.

TO DETERMINE A TABLE OF TIMES.

To determine the time of passage over the various arcs estimating from zero, it will be found convenient to apply logarithms to the formula previously deduced which should then be written $t = \frac{a\sqrt{R}}{\sqrt{\cos X}}$, R being the radius of the logarithmic tables, that is, 10,000,000,000.

From this we have

$$\log. t = \log. a + \tfrac{1}{2} \log. R - \tfrac{1}{2} \log. \cos x, \text{ or}$$
$$\log. t = \log. a + 5 - \tfrac{1}{2} \log. \cos x. \qquad \text{But}$$

$a = \frac{t''}{180\sqrt{}} = \frac{0''.378}{180\sqrt{2}} \therefore \log. a = \log. 0.378 - \frac{1}{2} \log. 64{,}800 = 3.171705$ and

$$\log. t = 2.171705 - \tfrac{1}{2} \log. \cos x,$$

final formula for determining the times for pendulums as now constructed.

If now x be made successively equal to 1°, 2°, 3°, &c., and the corresponding values of t be found, we shall have the time of passage of pendulum over each degree.

By adding the time of passage over the first degree to that over the second we shall have the time of passage over an arc of 2°. In the same manner, by adding this latter time to that of the third degree we shall have the time of passage over an arc of 3°, and so on.

The following table has been determined in this manner:

TABLE.

Degrees.	Time in seconds of passage over each degree.	Sum of times in seconds.	Degrees.	Time in seconds of passage over each degree.	Sum of times in seconds.
1	.00148504	.00148504	19	.00152749	.02849909
2	.00148538	.00297042	20	.00153174	.03003083
3	.00148594	.00445636	21	.00153684	.03156767
4	.00148673	.00594309	22	.00154213	.03310980
5	.00148775	.00743084	23	.00154772	.03465752
6	.00148901	.00891985	24	.00155361	.03621113
7	.00149049	.01041034	25	.00155980	.03777093
8	.00149221	.01190255	26	.00156630	.03933723
9	.00149415	.01339670	27	.00157313	.04091036
10	.00149633	.01489303	28	.00158029	.04249065
11	.00149876	.01639179	29	.00158780	.04407845
12	.00150142	.01789321	30	.00159565	.04567410
13	.00150433	.01939754	31	.00160388	.04727798
14	.00150749	.02090503	32	.00161248	.04889046
15	.00151089	.02241592	33	.00162147	.05051193
16	.00151455	.02393047	34	.00163087	.05214280
17	.00151847	.02544894	35	.00164070	.05378350
18	.00152266	.02697160	36	.00165092	.05543442

TO COMPUTE A SCALE OF VELOCITIES.

The times determined as just explained, it should be remembered, correspond to but half the difference of the arcs described by the two pendulums; therefore, they should be doubled in order to get the time between the falling of the pendulums or the successive cuttings of the wires. The distance between the targets being known, the velocity may be determined by dividing it by the time required by the projectile to move from one to the other. Let it be required, for instance, to determine the velocity corresponding to an arc of 15°, the target interval being 100 feet. On referring to the foregoing table we find the corresponding time to be 0''.02241592; doubling this we have 0''.04483184.

But the velocity, or $v = \frac{}{0''.04483184} \therefore$

$\log. v = \log. 100 - \log. 0.04483184 = 3.348243$ and $v = 2229.7$ feet.

The following table has been computed in the manner above explained:

BENTON'S ELECTRIC AND THREAD VELOCIMETERS.

Table of velocities, in feet, calculated for a distance of 100 feet between targets.

[Time of vibration of pendulum, 0″.378.]

	20°	21°	22°	23°	24°	25°	26°	27°
.	1665. 1	1583. 8	1510. 0	1442. 6	1380. 8	1223. 7	1270. 9	1222. 3
0°. 1	1656. 8	1576. 3	1503. 1	1436. 3	1375. 0	1318. 3	1265. 9	1217. 6
0°. 2	1648. 4	1568. 7	1496. 3	1430. 1	1369. 2	1313. 0	1261. 0	1213. 0
0°. 3	1640. 0	1561. 2	1489. 4	1423. 8	1363. 3	1307. 6	1256. 0	1208. 3
0°. 4	1631. 7	1553. 6	1482. 6	1417. 6	1357. 5	1302. 3	1251. 1	1203. 7
0°. 5	1623. 4	1546. 1	1475. 7	1411. 3	1351. 7	1296. 9	1246. 1	1199. 0
0°. 6	1615. 5	1538. 9	1469. 1	1405. 2	1346. 1	1291. 7	1241. 5	1194. 5
0°. 7	1607. 6	1531. 7	1462. 5	1399. 1	1340. 5	1286. 5	1237. 0	1190. 1
0°. 8	1599. 6	2524. 4	1455. 8	1393. 0	1334. 9	1281. 3	1232. 4	1185. 6
0°. 9	1591. 7	1517. 2	1449. 2	1386. 9	1329. 3	1276. 1	1227. 9	1181. 2

	28°	29°	30°	31°	32°	33°	34°	35°
	1176. 7	1134. 4	1094. 7	1057. 5	1022. 6	989. 8	958. 9	929. 6
0°. 1	1172. 4	1130. 4	1090. 9	1054. 0	1019. 3	986. 7	956 0	927. 8
0°. 2	1168. 1	1126. 4	1087. 2	1050. 5	1016. 0	983. 6	953. 0	924. 1
0°. 3	1163. 8	1122. 3	1083. 4	1046. 9	1012. 6	980. 5	950. 1	921. 3
0°. 4	1159. 5	1118. 3	1079. 7	1043. 4	1009. 3	977. 4	947. 2	918. 5
0°. 5	1155. 2	1114. 3	1075. 9	1039. 9	1006. 0	974. 3	944. 3	915. 7
0°. 6	1151. 0	1110. 4	1072. 2	1036. 4	1002. 8	971. 3	941. 3	913. 0
0°. 7	1146. 9	1106. 5	1068. 5	1033. 0	999. 5	968. 2	938. 4	910. 2
0°. 8	1142. 7	1102. 5	1064. 9	1029. 5	996. 3	965. 1	935. 5	907. 4
0°. 9	1138. 6	1098. 6	1061. 2	1026. 1	993. 0	962. 0	932. 5	904. 7

THE DISJUNCTOR.

For the purpose of ascertaining whether the machine is correctly adjusted, that is, whether the point of passage of the pendulums is at the

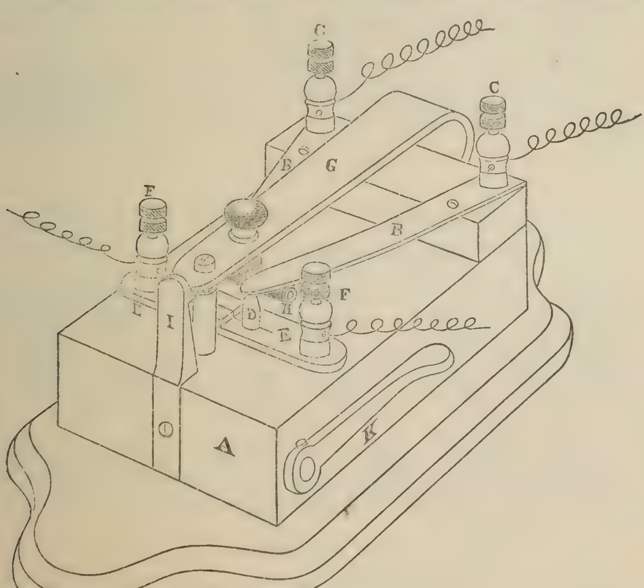


Fig. 2.

zero of the scale, an auxiliary instrument, shown in Fig. 2, is provided, which enables the currents to be made or interrupted at will. It consists of a wooden block, A, to which two spring blades, B B, through which the currents pass, are secured at rear by the binding-screw posts C C. When cocked the front ends of these blades are in contact with two small adjustable posts, D D, connected by brass plates, E E, with binding-screw posts, F F, at the front of the block. A heavy steel spring, G, fastened by screws to the rear of the block, supports a straight rod, H, coated with rubber or other insulating material, nearly at right angles to and below the blades B B. When the spring is pressed down a catch, I, operated by a concealed spring, holds it in place. By means of the trigger K the catch may be thrown back, when the spring rising causes the rod H to lift the blades from the small posts, breaking the currents and allowing the pendulums to fall. The cross-rod H is about an eighth of an inch below the blades when the instrument is cocked; it therefore acquires considerable momentum before reaching the blades, strikes them a blow and breaks the contact suddenly, preventing dragging. The front ends of the blades are very near together, which diminishes the liability of one current being broken before the other; the releasing of the spring by a trigger also tends to the same end, it having been found that the disjunction dot could be shifted by varying the pressure from one side to the other of the spring-catch, as originally constructed. This latest form, devised at the National Armory, is believed to be the most perfect yet proposed.

THE BATTERIES.

The batteries used with this machine, also proposed by Colonel Benton, are a modification of the Bunsen.

The outside cup is of cast-iron, and contains simply common salt and water. The porous cup holding the carbon is filled with a mixture of one part nitric and three parts dilute sulphuric acid. A perforated cast-iron cylinder surrounds the porous cup.

These batteries, though not so powerful as the Bunsen, are not subject to local currents, are very uniform in their action, and readily responsive to the closing of the circuit. They also possess the great merit of cheapness.

THE TARGETS.

For small arms a single wire stretched tautly across the muzzle of the gun is all that is necessary for the first target. A screen of about 8 inches in width and 4 inches in height, made by stretching the wire back and forth over small pins about $\frac{1}{4}$ of an inch apart, is a convenient size for the second target. A terminal plate target, as used at Frankford Arsenal, having a spring on its rear connected with the target wires, has been found to give very satisfactory results. The connection is broken by the shock of the bullet against the plate, and the spring automatically renews it.

For cannon the screens should be greatly enlarged, and the machine should be at such distance from the gun and so sheltered that the pendulums will not be jarred down before the wires are cut.

GENERAL ARRANGEMENT.

The following sketch illustrates the arrangement of the various parts for taking velocities:

A is the machine, B the disjunctor, C and D the batteries, E and F the targets, and G the gun.

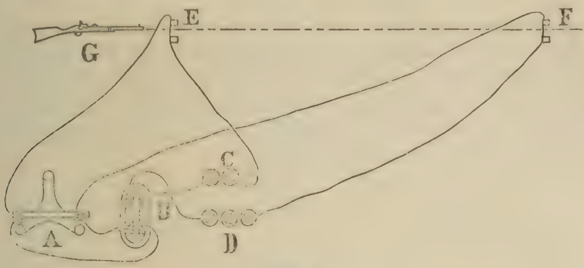


Fig. 3.

TO ADJUST THE MACHINE.

The batteries being in connection with the machine close the dis- junctor. Raise the pendulums to their corresponding magnets and touch the registering point with the blade of a knife lightly coated with printer's ink. Pull the trigger of the disjunctor. If the dot be at zero of the scale the adjustment is probably correct; it is, however, always well to repeat the operation. If the dot be at either side of the zero, turn the adjusting screw of the magnet on that side slightly to the right, so as to withdraw the magnets from the pendulum, or lower the one on the opposite side; close the disjunctor and proceed as before. The operation should be repeated until the dot coincides with the zero.

The adjustment can usually be made in a very few minutes. In practice it will be found advisable to withdraw the magnet connected with the most distant target from the pendulum until the least powder that will sustain the pendulum is found.

The other pendulum, which is connected with the first target, should then be adjusted to the second one. Resistance coils may be used for this purpose if necessary. By this means the least battery power that will do the work is made use of with less liability to error due to remaining magnetism. One great advantage of this machine is the trifling amount of power required, a single cell on each pendulum being amply sufficien.t

TO ADJUST THE DISJUNCTOR.

Adjust the machine, as before explained, bringing the dot exactly on the zero. Invert the circuits so that the currents shall pass each through the other blade. Take a disjunction. If the dot be found at the zero no adjustment is required. If found at the side of the zero opposite the magnet in the first circuit, turn out slightly the small post on which the blade rests, as the pendulum in this circuit falls too soon; if found on the same side adjust the other post; or, in either case, one may be turned out and the other in. Repeat the operation until the dot is found at zero with the currents passing through either blade.

TO TAKE VELOCITIES WITH THE MACHINE.

Place the first target in the circuit of one pendulum and battery, and the second in that of the other. Adjust the machine, close the disjunctor, suspend the pendulums, ink the point, and give the signal to fire. Pull

the trigger of the disjunctor. Read the arc from 0 to the dot and from the scale take the corresponding velocity in feet. Renew the targets, take a disjunction, and, if necessary, adjust the machine; then proceed as before.

ACCURACY OF THE MACHINE.

For the purpose of giving an idea of the extreme accuracy of this machine when properly constructed and carefully worked, the following record of velocities, taken at the National Armory during a period of several months, simultaneously with independent circuits, on this machine and the Le Boulengé chronograph, —one of the most reliable michro-chronometers known—is here given:

Date.	No. of shot.	Velocities.	
		Benton's electro-ballistic.	Le Boulengé chronograph.
Aug. 15, 1879.	1	1247. 9	1243. 1
	2	1245. 4	1244. 6
	3	1263. 2	1258. 3
	4	Wire not cut.	1263. 7
	5	1245. 4	1243. 1
	Mean	1250. 5	1250. 7
Aug. 15, 1879.	1	1199. 9	1192. 7
	2	Wire not cut.	1210. 3
	3	1191. 1	1184. 8
	4	1192. 9	1200. 5
	5	1191. 1	1184. 8
	Mean	1195. 4	1194. 6
Aug. 15, 1879.	1	1183. 4	1181. 4
	2	1172. 1	1171. 1
	3	1167. 5	1166. 2
	4	1150. 0	1148. 6
	5	1165. 2	1164. 2
	Mean	1167. 6	1166. 3
Oct. 14, 1879.	1	1345. 3	Wire not cut.
	2	1339. 4	1335. 7
	3	1357. 1	1342. 1
	4	1354. 1	1353. 4
	5	1339. 4	1335. 3
	6	1345. 3	1349. 5
	Mean	1346. 8	1343. 2
Oct. 14, 1869.	1	1345. 3	1344. 6
	2	1339. 4	1338. 7
	3	1339. 9	1341. 6
	4	1339. 4	1340. 6
	5	1351. 2	1349. 5
	Mean	1343.	1343.
Oct. 15, 1879.	1	1342. 3	1342. 6
	2	1322. 4	1324. 1
	3	1336. 5	1333. 8
	4	1351. 2	1353. 4
	5	1345. 3	1344. 6
	Mean	1339. 5	1337. 7
Oct. 15, 1879.	1	1330. 9	1325.
	2	1330. 9	1327. 9
	3	1330. 1	1331. 8
	4	1342. 4	1352. 4
	5	1342. 4	1342. 1
	6	1339. 4	1340. 6
	Mean	1336.	1336. 1

Date.	No. of shot.	Velocities.	
		Benton's electro-ballistic.	Le Boulengé chronograph.
Oct. 16, 1879.	1	1357. 1	1356. 3
	2	1351. 2	1352. 4
	3	1348. 3	1349. 0
	4	1357. 1	1361. 2
	5	1366. 1	1369. 1
	Mean.......	1356.	1357. 6
Oct. 16, 1879.	1	1348. 3	1349.
	2	1350. 1	1349. 5
	3	1348. 3	1349.
	4	1351. 2	1349.
	5	1339. 4	1342. 1
	Mean.......	1347. 5	1347. 7
Oct. 16, 1879.	1	1342. 3	1338. 7
	2	1351. 2	1349. 5
	3	1345. 3	1346. 5
	4	1352. 1	1351. 4
	5	1354. 1	1350. 4
	Mean.......	1349. 0	1347. 3
Oct. 17, 1879.	1	1357. 1	1356. 3
	2	1351. 2	1354. 2
	3	1348. 3	1349.
	4	1357. 1	1361. 2
	5	1366. 1	1369. 1
	Mean.......	1356.	1357. 6
Oct. 17, 1879.	1	1348. 3	1349.
	2	1350. 1	1349. 5
	3	1348. 3	1349.
	4	1351. 2	1349.
	5	1339. 4	1342. 1
	Mean.......	1347. 5	1347. 7
Oct. 17, 1879.	1	1342. 3	1338. 7
	2	1351. 2	1349. 5
	3	1345. 3	1346. 5
	4	1352. 1	1351. 4
	5	1354. 1	1350. 4
	Mean.......	1349.	1347. 3
Oct. 23, 1879.	1	1181. 1	Wire not cut.
	2	1195. 4	1194. 6
	3	1204. 3	1206. 9
	4	1204. 3	1201. 5
	5	1197. 4	1192. 7
	Mean.......	1196. 5	1198. 9
Nov. 1879.	1	1399. 3	1396. 5
	2	1384. 2	1378. 9
	3	1399. 3	1394. 5
	4	1396. 1	1398. 5
	5	1398. 3	1400. 4
	Mean.......	1395. 4	1393. 8
Jan. 14, 1880.	1	1346. 1	1346.
	2	1334. 9	1333.
	3	1334. 9	1336.
	4	1340. 5	1339.
	5	1343. 3	1345.
	Mean.......	1339. 9	1339. 8
Jan. 14, 1880.	1	1357. 5	1355.
	2	1346. 1	1346.
	3	1342. 3	1341.
	4	1351. 7	1349.
	5	1347. 1	1346.
	Mean.......	1348. 9	1347. 4

Date.	No. of shot.	Velocities.	
		Benton's electro-ballistic.	Le Boulengé chronograph.
Jan. 27, 1880.	1	1328.1	1327.9
	2	1340.4	1341.6
	3	1340.4	Wire not cut.
	4	1357.1	1359.3
	5	1351.2	1350.4
	Mean......	1343.4	1344.8
Jan. 27, 1880.	1	1263.2	1265.2
	2	1290.4	1287.7
	3	1266.8	1266.2
	4	1261.2	1260.8
	5	1294.8	1302.4
	Mean.......	1275.3	1276.5
Mean of all foregoing velocities		1314.9	1314.1

Difficulties with the earlier machines were experienced because of the fact that there were no means provided for regulating the power of the magnets, and still more from the faulty construction of the disjunctors issued with them. These, as first pointed out by Captain Prince, Ordnance Department, were not, in fact, disjunctors at all. Both currents passing through a single blade, its opening had the effect of throwing both batteries in the same circuit. Hence remaining magnetism, simply because the circuits were not broken.

THREAD VELOCIMETER.

A modification of the velocimeter before described, by which electricity for sustaining the pendulums is replaced by thread, has also been devised by Colonel Benton. The machine stands midway between the targets. In principle it is based on the loosening effect of a taut thread being transmitted through equal distances in equal times. Though not as reliable as the electric machine, it has been found to give very satisfactory results.

APPENDIX 22.

CARRIAGE FOR LOWELL BATTERY GUN.

[Three plates.]

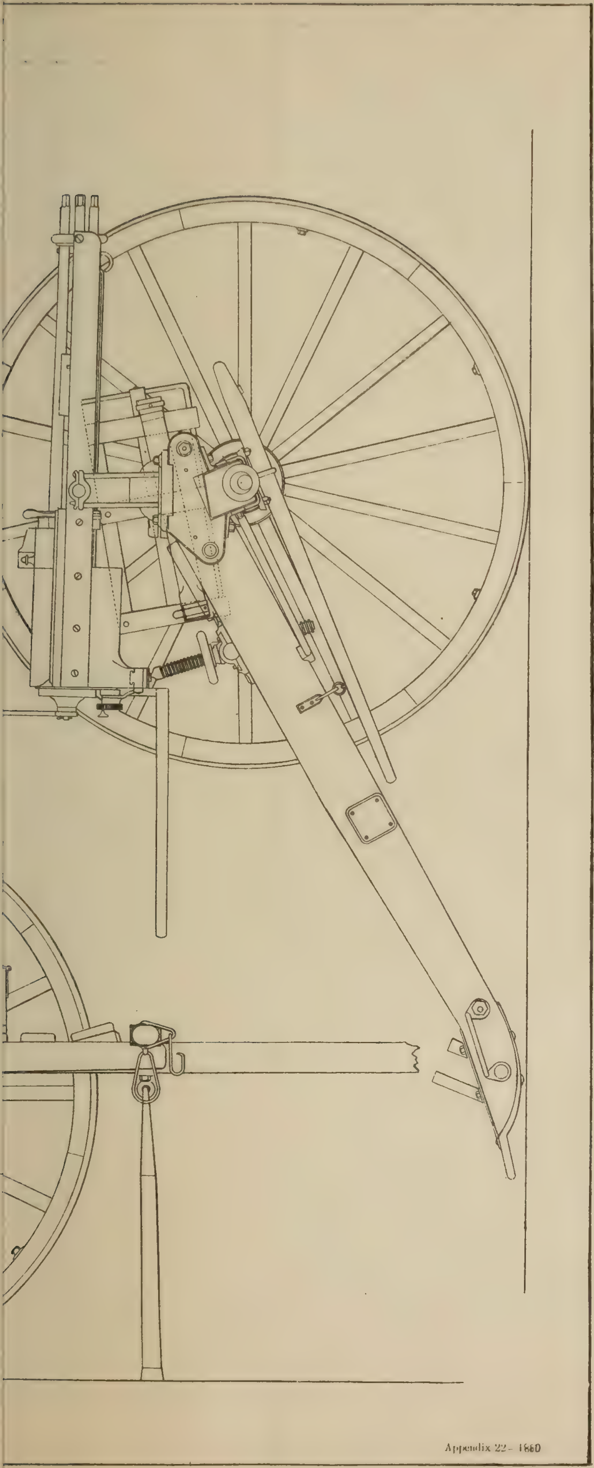
WATERVLIET ARSENAL,
West Troy, N. Y., May 21, 1880.

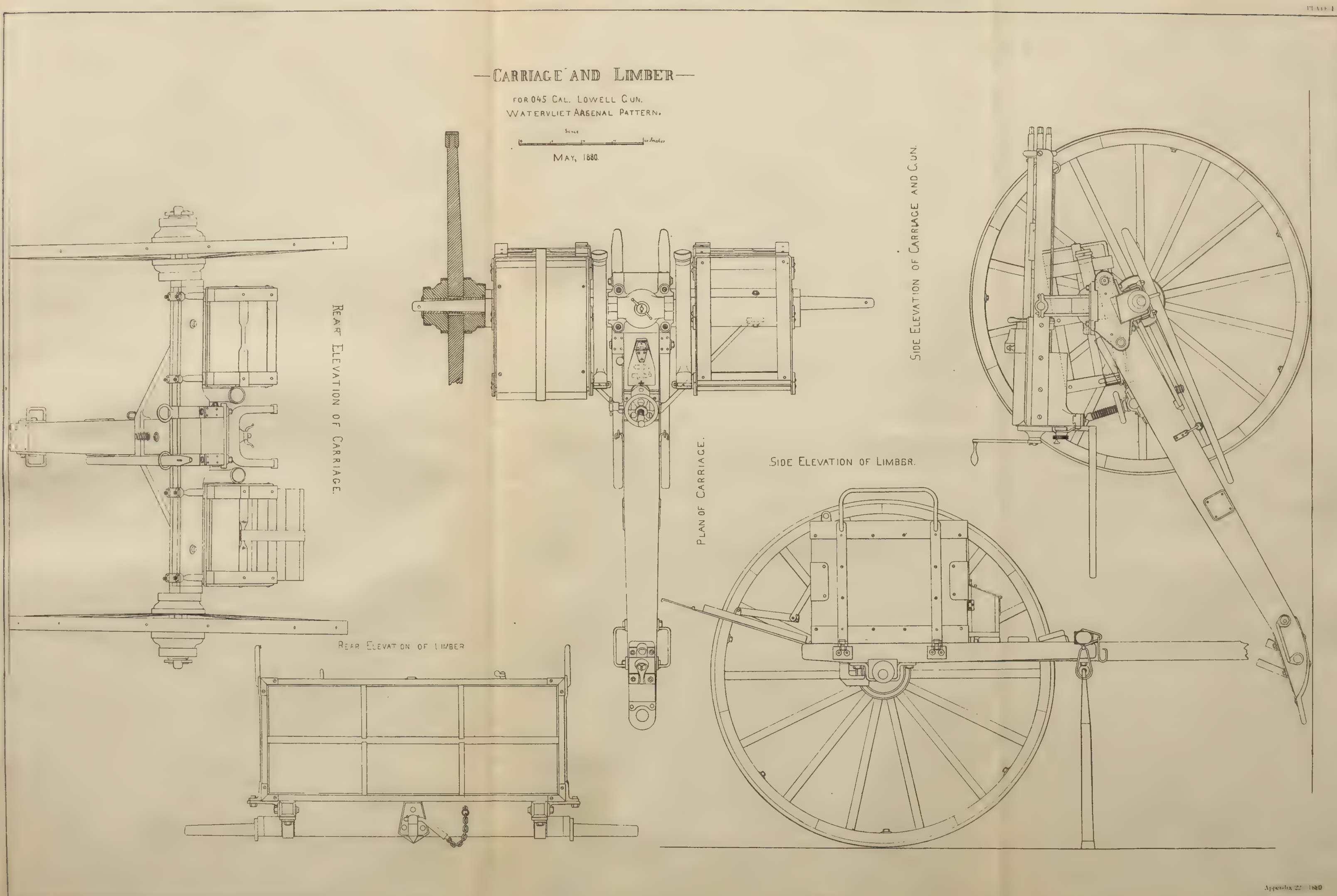
General S. V. BENÉT,
Chief of Ordnance, U. S. A., Washington, D. C.:

GENERAL: I have the honor to inclose three sheets of drawings, giving dimensions and details of construction of the carriage and limber for the Lowell battery gun, caliber .45″, fabricated at this arsenal under your instructions dated December 27, 1879.

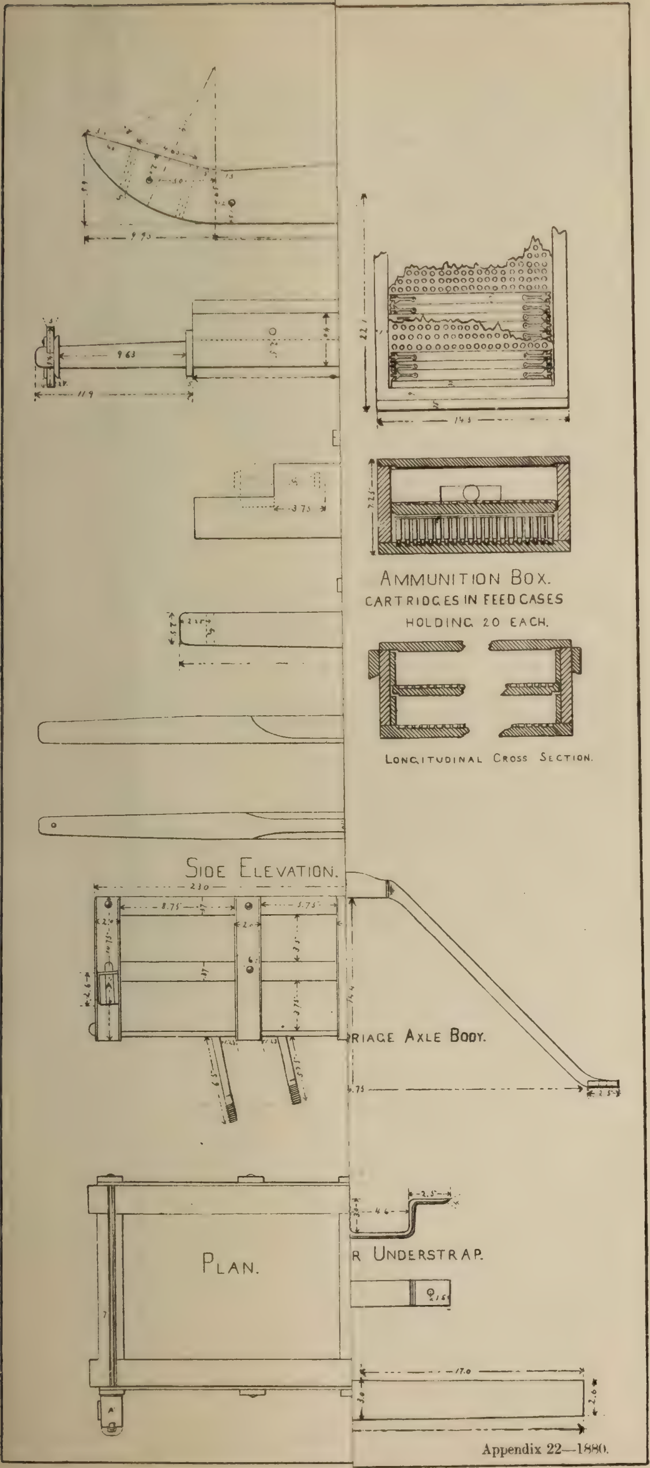
Very respectfully, your obedient servant,

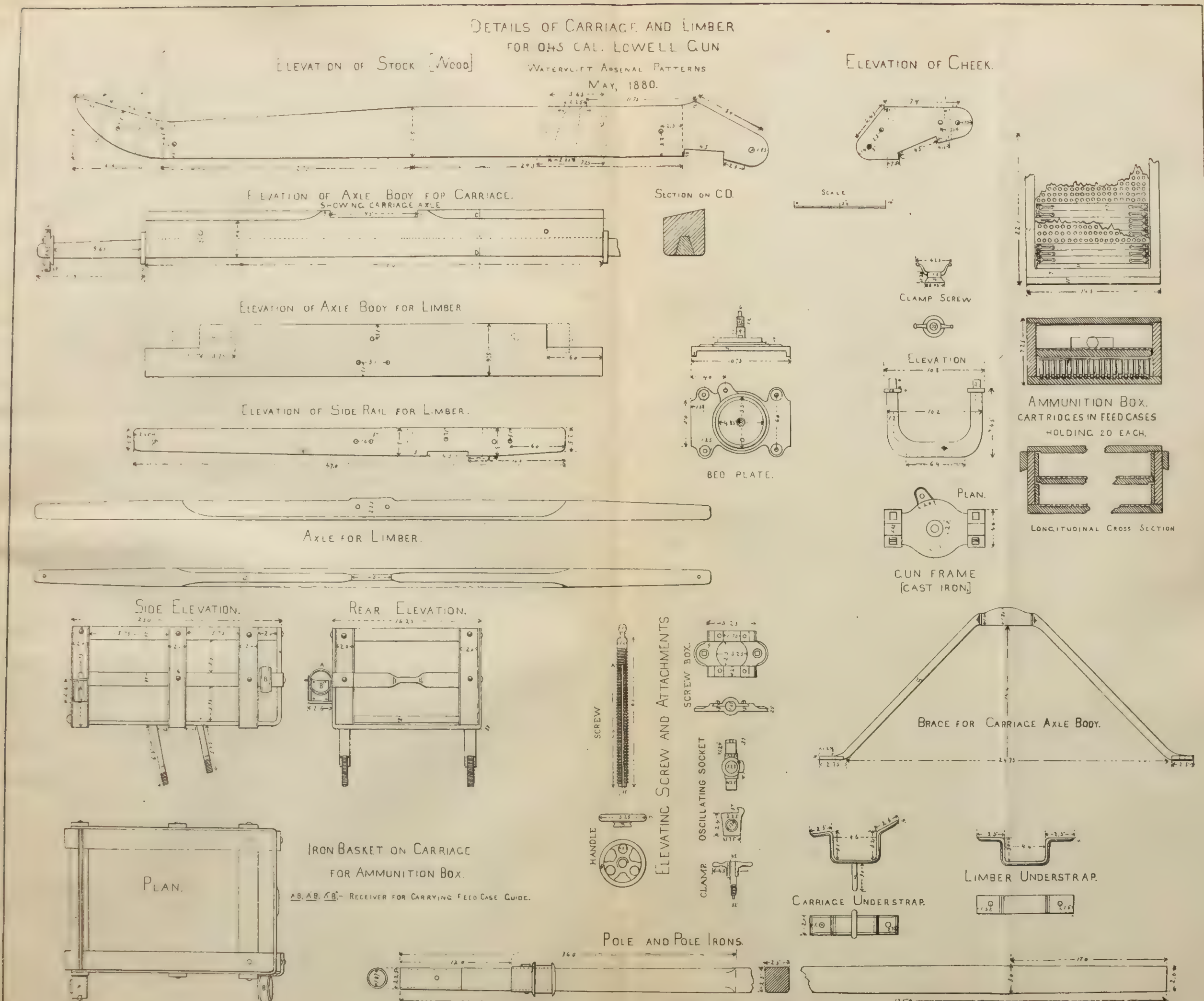
P. V. HAGNER,
Colonel of Ordnance, Commanding.

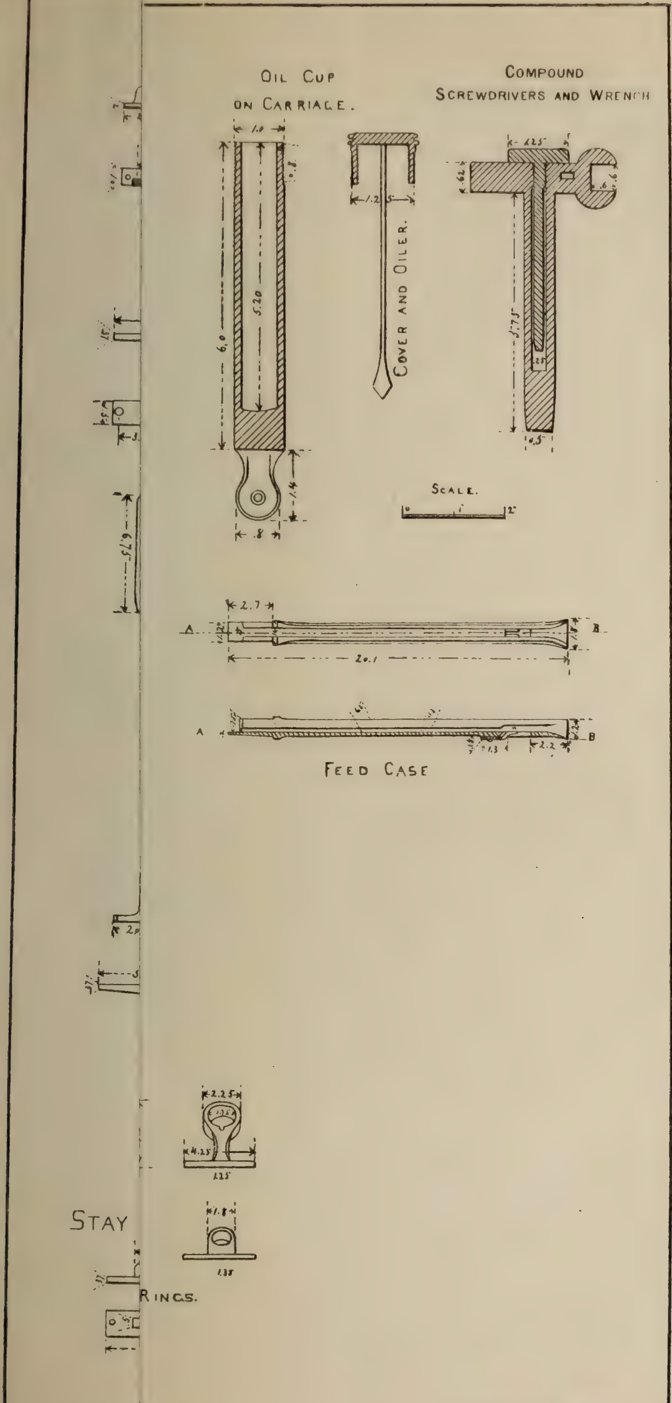




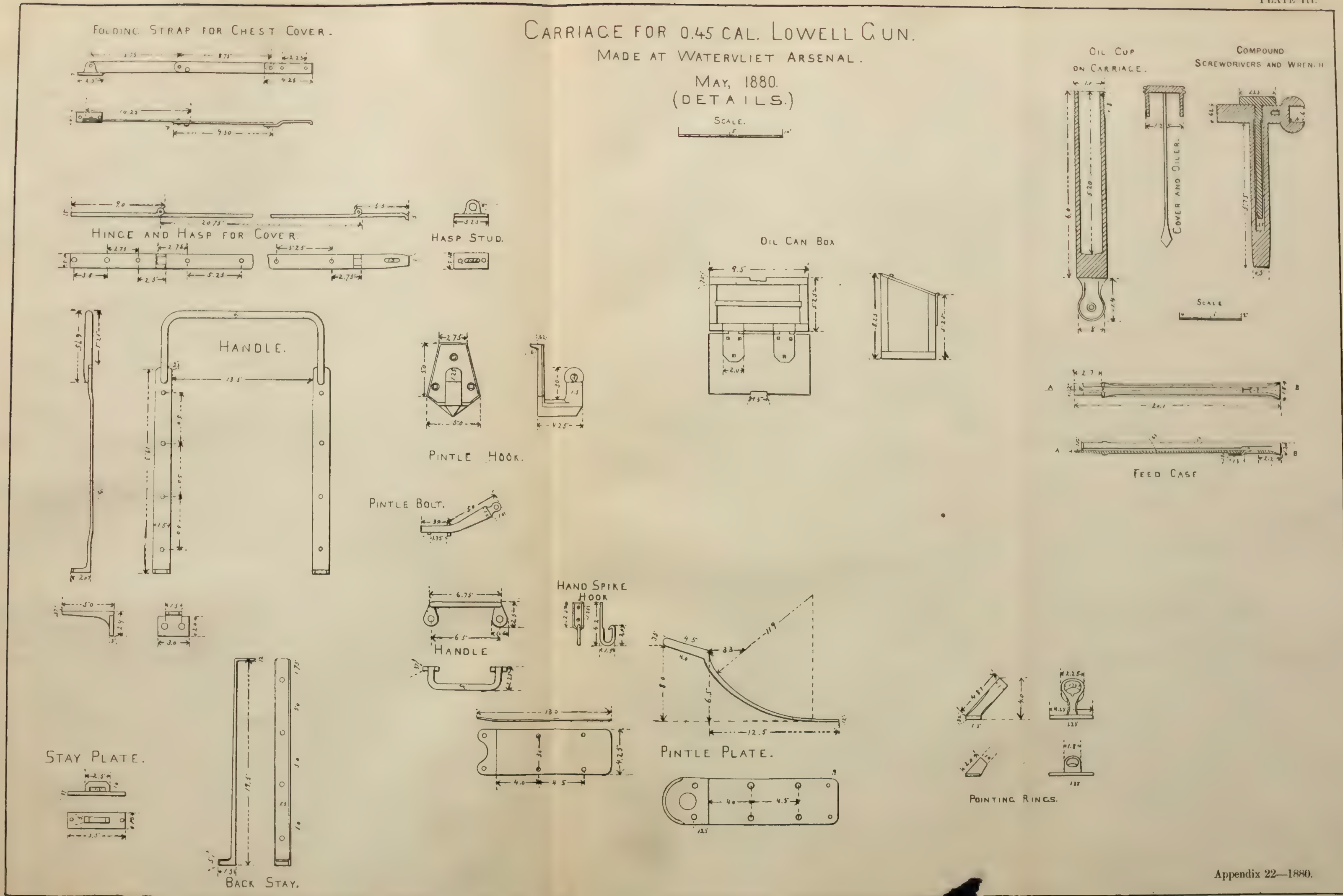
—CARRIAGE AND LIMBER—
FOR 045 CAL. LOWELL GUN.
WATERVLIET ARSENAL PATTERN.
Scale
MAY, 1880.
REAR ELEVATION OF CARRIAGE.
PLAN OF CARRIAGE.
SIDE ELEVATION OF CARRIAGE AND GUN.
SIDE ELEVATION OF LIMBER.
REAR ELEVATION OF LIMBER


AMMUNITION BOX.
CARTRIDGES IN FEED CASES
HOLDING 20 EACH.
LONGITUDINAL CROSS SECTION.
SIDE ELEVATION.
RIAGE AXLE BODY.
PLAN.
R UNDERSTRAP.


DETAILS OF CARRIAGE AND LIMBER
FOR 0.45 CAL. LOWELL GUN
WATERVLIET ARSENAL PATTERNS
MAY, 1880.
ELEVATION OF STOCK [WOOD]
ELEVATION OF CHEEK.
ELEVATION OF AXLE BODY FOR CARRIAGE.
SHOWING CARRIAGE AXLE
SECTION ON C.D.
SCALE
ELEVATION OF AXLE BODY FOR LIMBER
CLAMP SCREW
ELEVATION
ELEVATION OF SIDE RAIL FOR LIMBER.
BED PLATE.
AMMUNITION BOX.
CARTRIDGES IN FEED CASES
HOLDING 20 EACH.
PLAN.
LONGITUDINAL CROSS SECTION
AXLE FOR LIMBER.
GUN FRAME
[CAST IRON.]
SIDE ELEVATION.
REAR ELEVATION.
SCREW
ELEVATING SCREW AND ATTACHMENTS
SCREW BOX.
OSCILLATING SOCKET
BRACE FOR CARRIAGE AXLE BODY.
HANDLE
CLAMP.
PLAN.
IRON BASKET ON CARRIAGE
FOR AMMUNITION BOX.
AB. AB. AB. - RECEIVER FOR CARRYING FEED CASE GUIDE.
CARRIAGE UNDERSTRAP.
LIMBER UNDERSTRAP.
POLE AND POLE IRONS.



Appendix 22—1880.


CARRIAGE FOR 0.45 CAL. LOWELL GUN.
MADE AT WATERVLIET ARSENAL.
MAY, 1880.
(DETAILS.)
SCALE.
FOLDING STRAP FOR CHEST COVER.
HINGE AND HASP FOR COVER.
HASP STUD.
HANDLE.
PINTLE HOOK.
PINTLE BOLT.
OIL CAN BOX
OIL CUP ON CARRIAGE.
COVER AND OILER.
COMPOUND SCREWDRIVERS AND WRENCH
FEED CASE
HAND SPIKE HOOK
HANDLE
PINTLE PLATE.
STAY PLATE.
BACK STAY.
POINTING RINGS.

APPENDIX 23.

A REPORT ON THE WELDON RANGE-FINDER.

BY LIEUT. A. H. RUSSELL, UNDER THE DIRECTION OF COL. T. T. S. LAIDLEY, ORDNANCE DEPARTMENT.

[Two plates.]

A paper by Major J. B. Richardson, R. A., read before the R. A. Institution and furnished from the Ordnance Office, contains the only information as yet received concerning the Weldon range-finder, but from its incompleteness this information had to be supplemented by further investigation and experiment.

The account is as follows:

(Figs. 1 to 6 relate to this part.)

"The use of range finders in scientific warfare is recognized as a necessity by nearly all the military powers; but hitherto no satisfactory instrument has been forthcoming.

"To many a hard-working battery officer who has toiled wearily on, instructing men in the art of range-finding with the highly complicated instruments adopted in our service, happy if, by chance, he has succeeded in training, after hours and hours of instruction, say, one non-commissioned officer in his division to find ranges accurately enough for the result to be depended on, the news that an instrument has been invented simple enough for an uneducated man to work effectively will be most welcome.

"Such a system of range-finding has been perfected by Major Weldon, of the Madras Staff Corps. It may be taught to an intelligent man in an hour, and to men of poor education—the class with which one mostly has to deal—in from three to four hours. The instrument used is extremely simple, devoid of calculators, verniers, cylinders, screws, springs, racks, or anything likely to get out of order; extremely portable, and so cheap that every non-commissioned officer might possess one and carry it in his pocket. By this system a range may be found in the time that it takes to dismount and put a Nolan's instrument together, or while with a Watkins' the horses are being knee-haltered and the pickets being planted; and the ranges found can be depended upon.

"All range-finders depend for the accuracy of result on the length of the base. When the base subtends an angle of less than 2° the result is unreliable, unless instruments are used far too delicate for rough service work. Again, if the angle subtended by the base is greater than 3° the base is unnecessarily long. In all range-finders worked with an arbitrary base the error increases with the distance. Major Weldon's system secures unvarying reliability at all ranges, by making the base proportional to the sides of the triangle, which converge on the distant object. He reasoned thus (Fig. 1, Pl. 1):

"In an isosceles triangle, A B C, of which the angles A B C, A C B are each 88° 34′ 3″ and A D is a perpendicular,

$$\begin{aligned} A\,B &= B\,D \text{ sec. } 88^\circ\ 34'\ 3'' \\ &= \frac{B\,C}{2} \times 40 \\ &= 20\ B\,C. \end{aligned}$$

"He applies this reasoning practically, thus:

"Suppose an observer (Fig. 2, Pl. 1) at C, with an instrument capable of reflecting an angle of 88° 34′ 3″, sees A reflected along a line C F. If an observer provided with a similar instrument moves in the direction F to C, he will arrive at a point, B, where he will see A reflected on C. A B C will then be an isosceles triangle having the angles A B C, A C B each = 88° 34′ 3″, and twenty times the base B C will equal A B or A C.

"Or, suppose there is only one instrument forthcoming, then the observer, by using two pickets, can obtain the same result.

"Planting a picket, D (Fig. 3, Pl. 1), at random, he moves until he finds at C a place where A is reflected along the line C D F, and here he again plants a picket. Moving along the line C F, he arrives at a spot, B, where A is reflected on the line of the pickets D and C. As before, twenty times B C = A B or A C.

"After some years spent in attempts to obtain the satisfactory reflection of an angle of 88° 34′ 3″, Major Weldon has now introduced an instrument so simple that until used it is difficult to believe that with such an apparent toy distances varying from a few yards to many thousands of yards can be accurately measured. Its cost, at present, is about thirty shillings. It is little larger than a walnut, weighs but a few ounces, and can be carried in a small pocket. It requires no adjustment, and will stand rough usage.

"It consists of a plate-glass prism, bound in brass (Fig. 4, Pl.), having the angle B A C carefully ground to 88° 34′ 3″, the back, B D E C, being silvered, so as to act as a mirror. Its cost is great, owing to the care which has to be given to cutting the angle accurately. In practice, this instrument, small as it is, is found to work perfectly, giving ranges with great accuracy.

"The drawing (Fig. 5, Pl. 1) will explain its use. The sketch is necessarily much exaggerated. It is required to find the distance of the palm tree, A: The observer moves along the line C F until he sees the palm tree and the eye of the soldier at C coincide. The soldier at C, provided with a similar instrument, sees the palm tree and the eye of the observer at B reflected in a similar way. Then each of the angles A B C, A C B = 88° 34′ 3″, and A C = 20 B C.

"Major Weldon also works with another instrument, rather larger and perhaps slightly more complicated, but nevertheless extremely simple. It is far cheaper than the last described—costing about fifteen shillings—and is easy of adjustment. The instrument (Fig. 6, Pl. 2) consists of a solid brass case, H G I J K, in the form of a segment of a cylinder, the apex angle being taken greater than 89°, having two oblong openings, W, in each side, and underneath each of these windows a block, K, in which is fixed a mirror, M. The block on the left-hand side is firmly fixed with screws, but the block on the right is capable of slight adjustment by screws at L. The mirrors are inclined to one another at an angle of 88° 34′ 3″. A handle, P, is screwed to the case for convenience in using the instrument, and there is a loop at the end of this handle to admit of the attachment of a lanyard, so that it may be carried round the neck and stowed away in a pocket without being liable to a fall.

"When using the instrument it must be held with the open side toward the eye, but nearly half turned in the direction of the object to be reflected, so that on looking into the instrument only one reflector is visible, in which will be seen objects to the right or left of the observer.

"Major Weldon's directions for finding the range exhibit the practical working of the instrument:

"'To find the range with two men, No. 1 goes to the right and finds the angle; No. 2 goes to the left and finds the base: the two men stand facing the object. They carefully note and agree on some prominent point on it to be observed in the angle-glass.

"'They then turn outward, note the particular spot on the ground in front of each that coincides with the reflected object, and march straight on the spot until they reach the estimated length of base.

"'They now turn inward, and No. 2 stands steady while No. 1, moving, makes an angle with him and the object, and when that is effected he stands steady. No. 2 now sees in the angle-glass whether the reflected object falls to the right or left of No. 1. If on the right, No. 2 must retire to increase his distance from No. 1; if on the left, he must advance to lessen his distance. After each move No. 2 halts and stands steady for No. 1 to make a fresh angle. In this manner Nos. 1 and 2 alternately move and halt until they get the object fairly reflected on each other. The distance between them is then measured to determine the range of the object.'

"In practice Major Weldon either paces the base (which, from practice, he does very correctly, and obtains very fairly accurate results), or he measures it by a line of thin cobbler's twine—a material he finds to answer better than tapes, &c. Of this line he carries 150 yards (answering to a 3,000 yards' range), wound on a simply-constructed reel, marked and numbered at every five yards. Each of these marks corresponds to 100 yards of range, and is so figured. No strain comes on this line. hTe man measuring moves straight from point to point; the line, as it unwinds from the reels, lies fair on the ground.

"In rewinding the man walks rapidly back winding up as he goes, instead of pulling the line to him. The wooden disk or reel for 150 yards of this measuring twine is so thin that it can be used in the highest wind.

"The ease with which the range of moving objects is obtained by two observers with the Weldon instruments is very remarkable; but for such objects practiced men are required. The distance of infantry firing from under cover has been ascertained by the puff of smoke from their rifles. The position of hidden guns could doubtless be obtained in the same manner."

REMARKS.

A prism instrument made in London in the manner above described accompanied the paper. It will be referred to hereafter as prism No. 1.

This instrument, when tested, would not give the required reflection of 88° 34′ 3″, but gave a variable angle greater than 90°, showing that its construction was faulty, and the description given in the above paper incomplete. The theory and use of the instrument are, however, correctly given.

Another prism was, therefore, prepared, differing from prism No. 1 in the following particulars:

While No. 1 was so constructed that the two base angles were equal, as shown in Fig. 4, Pl. 1, 4 (A B C = A C B), No. 2 was required to have one of these angles equal to one-half the third angle; or, A B C = ½ B A C.

The course of light in the prism is indicated in Fig. 7 (Pl. 2), which shows a horizontal section of the prism. The light from the object at *a* enters at the surface A B; is then refracted more nearly normal to this surface; is then reflected internally from the silvered surface B C, and again internally from the unsilvered surface A B; passing out through the surface A C, where it is again refracted, but away from the normal, and reaching the eye of the observer at *f*. The angle *f a′ b*, between *f e*

prolonged and *a b*, is the deviation of the light, or the angle reflected by the prism.

It is evident that the deviation would be the same if the observer and the object changed places, the course of the ray passing from *f* to *a* along the broken line *a b c d e f* instead of from *a* to *f*.

The reason for making the angle B one-half the angle A appears from the following discussion:

After the light enters the prism the two surfaces A B and B C act as mirrors, and, from the well-known principle that light reflected twice from a combination of two plane mirrors undergoes a deviation equal to twice the angle of the mirrors, the angle made by *d e* with *c b* is twice the angle B. In order now that this deviation shall not be changed by refraction in passing through the surfaces A B and A C, the rays *b c* and *d e* should make equal angles with the latter surfaces—that is, B *b c* should be equal to A *e d*. The refraction will then be the same at both surfaces.

The following relations subsist among the angles in Fig. 7:

$$\mathrm{B}\ c\ b = 180^\circ - \mathrm{B} - \mathrm{B}\ b\ c = \mathrm{C}\ c\ d,$$
$$\mathrm{B}\ d\ c = \mathrm{C}\ c\ d - \mathrm{B} = 180^\circ - 2\ \mathrm{B} - \mathrm{B}\ b\ c = \mathrm{A}\ d\ e,$$
$$\mathrm{A} = 180^\circ - \mathrm{A}\ e\ d - \mathrm{A}\ d\ e = 180^\circ - \mathrm{A}\ e\ d - (180^\circ - 2\ \mathrm{B} - \mathrm{B}\ b\ c).$$

Now, since A *e d* must be equal to B *b c*, A must be made equal to 2 B in order to obtain an invariable deviation equal to A.

To give a deviation of 90°, A should be 90°; B and C each 45°. In this form it can be used as a *camera-lucida*.

For a deviation of 88° 34′ 3″, A should be 88° 34′ 3″, and B 44° 17′ 1″.5. In this case C, not being equal to B, the angle B should alone be used for determining the deviation.

In prism No. 1, A is less than 90°, and B, which is equal to C, is greater than 45°. The deviation will therefore be variable, and greater than 90°.

These results are confirmed by observation.

It is evident that the deviation given by the prism is chiefly dependent upon the angle B, because a slight error in B produces twice that change in the deviation; a slight error in A affects the deviation only by a slight difference in refraction at the two surfaces, and though the deviation will not be invariable, it will change but slightly. This is illustrated with prism No. 2, in which B is not exactly one-half A. It requires, also, the multiplier 18.3 instead of 20. The table below shows, however, that very good results can be obtained with it as it is, and doubtless less variation would occur in the measurements were the prism accurately ground. Accurate grinding was found to be difficult with the instruments at command, but the defect can be readily supplied if more prisms are required.

The cost of prism No. 2 was $12, but Mr. Alvan Clark, who made it, estimates that a number could be made correctly for about $2 apiece, as several could be ground together.

It is altogether probable that the true Weldon prism is similar to prism No. 2, and that prism No. 1 was made from the imperfect description given in Major Richardson's paper, where no allusion is made to the size of angles B and C.

Fig. 8 (Pl. 1) shows a modification of the frame of the prism found convenient in practice. A metal screen, B D D′ B′, perpendicular to the back, projects at the side next the angle B, and this serves to cut off annoying reflections, while it prevents the use of the wrong angle in observing. To obtain the reflection of an object on the observer's right he looks into the face A C C′ A′ in a direction nearly parallel to C B, and

for an object on his left he looks into the face A B B′ A′ in a direction nearly parallel to D B. If the prism is ever moved from its frame, care must be taken to place the smallest angle next the screen.

A serious difficulty arises in using the instrument when the ground is not very open, as it is then often impossible to see, from both ends of the required base, the object whose distance is desired. This difficulty would be likely to arise to some degree with most range-finders dependent on angular measurements, unless, as in the Berdan telemeter, the base were very short. The trouble could be considerably reduced by using in connection with the Weldon range-finder a prism made to reflect an angle of 90°, such as that described above. One observer having fixed the point C (Fig. 3) with the Weldon instrument, another observer with the right-angled prism moves along the line C D F until he sees A reflected from the direction C. He will then be at D, midway between C and B, and in this way an obstacle to the view from B might be avoided. The new base being half the usual one, the multiplier would have to be twice that required for the Weldon instrument alone, and the error of observation would be somewhat increased. The right-angled prism and the Weldon prism might be fixed back to back on the same frame, so that each observer should have both at command. No screen would be needed for the right-angled prism.

Major Richardson's description of the instrument shown in Fig. 6 is also evidently incorrect. Instead of an inclination of 88° 34′ 3″ for the mirrors, it should be half that, or 44° 17′ 1″.5, to give a deviation of 88° 34′ 3″. The angle H G I need be only about 45°, instead of a little over 89°.

Fig. 9 (Pl. 2) shows, in plan, a proposed instrument in which the mirrors can be adjusted at will for an angle of 44° 17′ 1″.5, or of 45°, so as to give a deviation of 88° 34′ 3″, or of 90°. This is for use in place of the two prisms described above. It is partly suggested by the Watkins (see Ord. Note 116) and partly by the Weldon range-finder. It is simpler than the former and not so limited in use as the latter, since it permits the employment of two lengths of base.

The mirrors M and M′ are attached to the frame F, M being arranged to turn on the pivot at *m*. The adjusting-screws K and L limit the motion, L being set to give an inclination of 45°, and K of 44° 17′ 1″.5. It can be used either with or without the telescope T, indicated in the figure, and it is evident that a telescope could also be applied to the prism instrument if desired. The form shown in Fig. 6 could be retained, and the mirror M arranged to move between limits fixed by adjusting-screws, as described for Fig. 9.

No experiments were made to time the observations, but measurements were made very rapidly with the single instrument. Two observers working together would greatly hasten the operation, and probably obtain a measurement in two or three minutes. The results given in the table were obtained by a single observer.

The measuring twine and reel mentioned in Major Richardson's paper were not used, an ordinary tape-measure being employed.

In using either of the instruments care must be taken to keep the reflecting surfaces vertical, and some little variation is likely to arise when the observer is much above or below the object sighted on. The faint reflection from the surfaces of the prism is of some assistance in determining when the instrument is erect.

Another form of prism is suggested by the Wollaston prism used in the camera-lucida, of which a section is shown in Fig. 10, A being 90° and D 135°; light passing along the broken line *a b c d e f* is deflected

90°. For any other angle of deflection, A should be made equal to this required angle and D should be $180° \frac{A}{2}$. For a deviation of 88° 34′ 3″, A should be 88° 34′ 3″, and D 135° 42′ 58″.5.

Thanks are due to Professors Cross and Henck, and to Mr. Holman, of the Institute of Technology; to Mr. J. Rayner Edmands, of the Cambridge Observatory; and to Professor Cook and Mr. Melville, of Harvard College, for the use of instruments and for valuable measurements.

CONCLUSIONS.

For open ground the Weldon range-finder would be very useful, and for general use, particularly if made adjustable to two lengths of base, it is probably as good as any instrument combining such advantages of compactness and simplicity. It might be found useful in the hands of officers in the field, particularly on the plains.

Table of results with prism No. 2.

(But one instrument was used. It was mounted as in Fig. 8, Pl. 1.)

Distance.	By range-finder.		Error of observation.	
	First trial.	Second trial.	First trial.	Second trial.
Yards.	*Yards.*	*Yards.*	*Yards.*	*Yards.*
379	382	378	+ 3	− 1
473	470	469.7	− 3	− 3.3
663	687	656	+ 24	− 7
796	800	811	+ 4	+15
840	819	855	− 21	+15
890	954	854	+ 64	−36
1,289	1,308	1,302	+ 19	+13
1,877	*1,982	1,867	*+105	−10
2,045	†2,092	2,043	†+ 47	− 2
2,100	*2,056	2,104	*− 44	+ 4
2,248	2,306	2,324	+ 58	+76

*Uncertain. † Measurement of base uncertain.

Some of the above irregularities probably arose from not keeping the instrument erect.

Fig. 1.

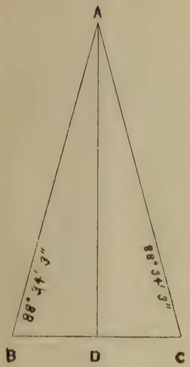


Fig. 2.

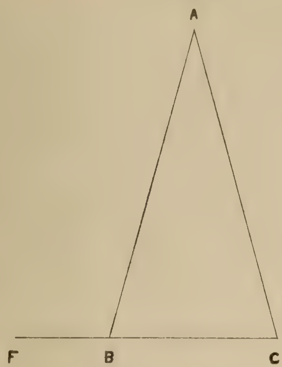


Fig. 3.

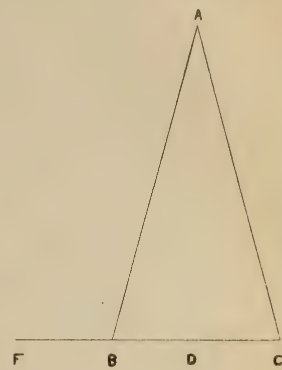


Fig. 5.

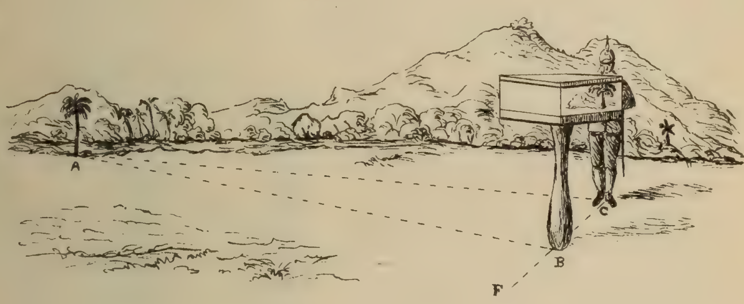


Fig. 4.

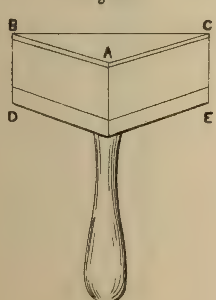


Fig. 8

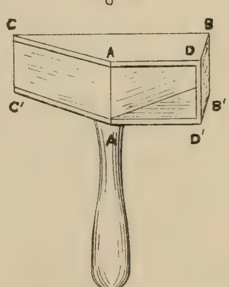


Fig. 7.

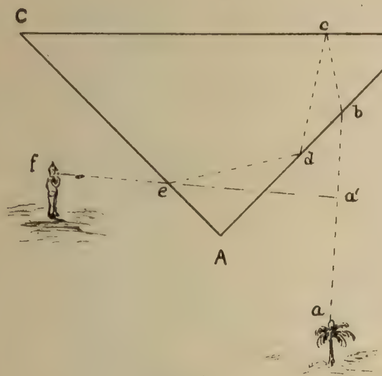


Fig. 10.

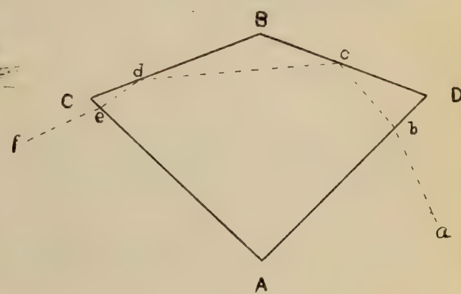


Fig. 6.

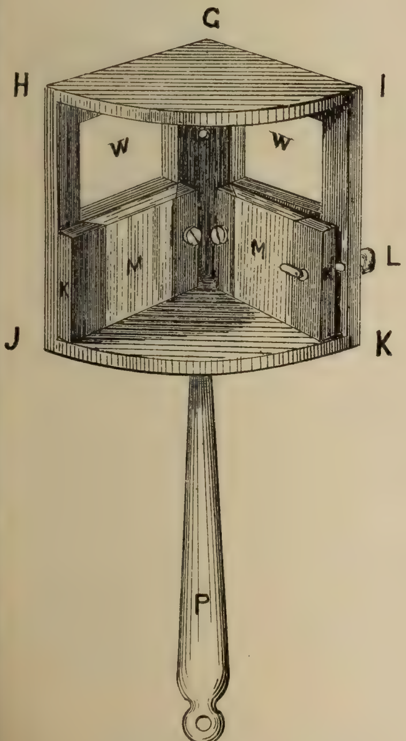
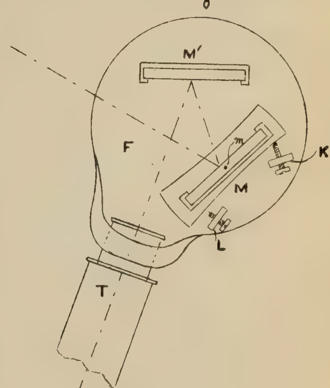


Fig. 9.



APPENDIX 24.

INSTRUCTIONS FOR THE CARE AND USE OF THE FRANKFORD ARSENAL HAND TOOLS FOR RELOADING CARTRIDGES.

BY LIEUT. COL. J. M. WHITTEMORE, ORDNANCE DEPARTMENT.

(One plate.)

Modified instructions for the care and use of the Frankford Arsenal hand tools for reloading cartridges furnished by the Ordnance Department.

RELOADING CARTRIDGES.

The reloading cartridges furnished to the army are the following:

Frankford Arsenal, solid head.
Lowell, solid head.
Winchester, solid head.
Berdan, folded head.

The Frankford Arsenal, Lowell, and Winchester cartridges have a central vent in the primer pocket, which admits of the exploded primer being driven out of the pocket from the inside of the empty shell by a punch.

The Berdan, having no central vent, requires a special tool, applied on the outside, to remove the exploded primer.

SPECIAL PRECAUTIONS FOR RELOADING CARTRIDGES.

Inspect all shells for defects, and reject all imperfect shells.

Never attempt to prime a loaded shell.

Resize shells after every round.

Too much or too little lubricant on cartridge or chamber of gun is injurious to both.

The set of Frankford Arsenal hand tools for reloading cartridges consists of:

Name.	Cost price	Name.	Cost price.
1 brush wiper	$0 10	1 punch, primer	25
1 charger	05	1 punch, reloading die	25
1 die, crimping	1 00	1 punch, resizing die	25
1 die, reloading	75	1 safety socket	25
1 die, resizing	1 75	1 scraper, shell	10
1 drift	05	1 setter, primer	1 25
1 extractor, primer	1 00	1 wiping rod	10
1 funnel	10	1 box containing set	35
1 mallet	15		
1 oil cup	25	Total cost of set	9 00
1 priming tool, "Bridgeport"	1 00		

MATERIALS.

The materials required comprise lubricated bullets, musket powder, and cartridge primers adapted to the shells to be reloaded. The bullets are issued in paper boxes containing 50 each; the powder in tin canisters or in barrels, inclosed in cotton-drilling bags.

The primers are issued in boxes containing 250 each.

CARE OF TOOLS.

The tools should be kept clean, well oiled, and in a dry place, especially at the sea-coast posts.

Grease or oil used should be free from salt or acid. Lard or paraffine oil will answer.

After use they should be cleaned by thoroughly wiping and oiling.

Never scour or polish them with any gritty substance.

GENERAL REMARKS ON CARE OF TOOLS.

Reloading tools should be used with a great deal of care, otherwise they are soon worn out and the Department put to unnecessary expense in replacing them. With proper use they will last for many thousand rounds.

The resizing die is about five-thousandths of an inch less in diameter than the average chamber of the gun, hence it will be seen that each shell should be clean on the outside before being inserted in the die for resizing, and, if possible, slightly oiled.

Equal care should be exercised with the crimping die. The very slight contraction of its interior surface, which does the crimping, can be very easily worn away and the die made worthless unless used with proper care.

The shoulder of the reloading punch should be kept clean and free from lubricant of bullets, so that it can drive the bullet home into the shell; also the mouth of the reloading die, to facilitate driving the bullet home.

After use, these tools, particularly the resizing and crimping dies, should be wiped clean and oiled to prevent their wearing away from rust.

The first practice with these tools should be under the personal supervision of an officer, and as frequently so as possible.

In using the mallet, soldiers should be selected and taught who can drive shells into resizing die with steady and straight blows on the head of the shell, otherwise its lifetime will be diminished and shells unnecessarily wasted.

Tools that *must be* made to work within such close limits cannot take care of themselves, and will certainly get out of order unless these precautions are taken, although made as strong and as simple as possible.

RELOADING.

After firing, the shells should be extracted from the gun without allowing them to fall on the ground, and placed in a box. This plan will save trouble in cleaning off grit or sand, and assist in preserving the tools.

The first operation of reloading is the removal of the exploded primer. For central-vent cartridges this is done by inserting the extractor in the shell and resting the head of the latter in the recess for it on the safety-socket, then drive out the primer with the mallet.

The Bridgeport tool for exterior extraction, and specially adapted to the "Berdan" shells, may be used for all cartridges; but the primer punch for central-vent shells is the more simple and positive in its action. If the wire of the extractor should break, extra ones are supplied with each set of tools, and are put in by unscrewing the plug in the head of the extractor, driving out the broken pin with the new one in the direction of the head, the hole being tapered, dropping in the new pin at the head and replacing the screw plug.

The shells, whether old or recently fired, should always, if possible, be cleaned of the powder residue, &c., by immersion and agitation in hot water. Cold water will clean them, but hot water is a better solvent, and the shells dry more quickly when taken out of it.

When circumstances render it impossible or inconvenient to use water, the brush wiper may be used for brushing out the residuum left in the shell by the combustion of powder and fulminate.

After cleaning, examine the shell to ascertain if it shows signs of rupture. These may generally be seen either at the head, the mouth, or as transverse or longitudinal marks on the body. *Reject all such shells.*

The shell is next forced into the die for resizing, using the mallet if necessary, striking fairly and squarely on the head of the shell, so as to avoid bending or distorting its flange.

The outside of the shell or inside of the die should be oiled to facilitate the entrance of the shell and prevent abrasion. It is driven out by means of the punch inserted in the die and shell.

This last operation is likely to cause a bur on the mouth of the shell, which would deface the bullet if not removed.

For this purpose the scraper is supplied. Insert it about 0″.5 into the shell, held in left hand, scraper in right; give the shell and scraper a half-turn in opposite directions, bearing with the scraper *only hard enough* to take off the bur.

The handle of scraper and axis of shell should be kept nearly parallel to each other to avoid thinning the mouth of the shell.

Although the shell may be fired several times without resizing, this operation is considered *necessary after each round*, otherwise the shell will be unduly expanded by successive rounds and eventually fail to enter the gun-chamber; after which the extra force required to resize it might prove injurious to the metal.

The shell is next inserted in the loading die, the primer entered into the pocket and the safety-socket placed over it, large end down; the primer may then be driven home with the primer-punch and mallet.

Considerable loss of primers by premature explosion in this operation has occurred, and a tool is supplied for setting primers by pressure, which is used as follows:

The shell is placed in the tool for inserting primers—the primer having been previously just entered in the pocket—and the primer pressed home by means of the lever and screw.

The end of the screw is so formed as to insure the primer being below the surface of the head at least 0″.005.

It should be slightly lubricated to avoid wear of the projection on the end and abrasion of the primer.

The "Bridgeport" tool may also be used to set the primers of all shells but the "Lowell," which has, intentionally, a primer to fit the pocket tightly, and requires considerable force for it proper insertion.

The screw tool will set the "Frankford Arsenal," "Berdan," "Lowell," and "Winchester" primers equally well.

Never attempt to prime a loaded shell.

The shell is now ready for reloading.

It is inserted in the loaded die, the latter into the safety-socket, and the powder-funnel into the mouth of the die.

A level measureful of powder is then poured into the shell through the funnel, after which the bullet is inserted and driven home with the punch and mallet until the shoulder of the punch touches the end of the die.

This insures proper and uniform length of cartridge.

The wooden drift is used to drive the loaded cartridge out of the die.

The reloading die may be used as a gauge for determining whether cartridges are of the proper dimensions for entering the chambers of guns. As a rule, any cartridge that will enter the reloading die will enter the chamber of the gun freely. It is in fact a combined reloading die and gauge for cartridges. To use it as a gauge insert the punch in the small end and the cartridge in the opposite end. If the cartridge enters fully without moving the punch, it is of proper length and diameter.

When shells are reloaded for immediate use they may be fired after the foregoing operation. But if loaded for storage for any length of time, the crimping die should be used to secure the bullet in position.

To perform this operation, insert the loaded cartridge into the die, then set the head in the recess of the safety-socket, the latter resting on a bench or table, and drive the cartridge in with the blows of the mallet on top of the die.

The safety-socket has a central hole concentric with the counter-bore. In extracting the primers it supports the head of the case and forms a receptacle for exploded primers. It also supports the head of the shell on opposite ends in the operations of loading and crimping, and the central hole protects the primer from severe shocks in driving home the bullet, and it also guides the punch in setting the primers.

The wiping-rod serves to clean out the bore of the dies, &c., by means of cotton-waste or a rag drawn through the slot in its end.

Particular care should be taken to free the exterior of the shell from grit or dirt before resizing, to protect the die and shell from scratches; also, that neither water nor oil gets into the case or primer, as either will injure or destroy the powder or fulminate.

No *excess* of oil should be left in the chamber of the gun or on the cartridge, as it would tend to rupture the case in firing and temporarily disable the gun.

A slight amount of lubricant on the cartridge or chamber throughout their length seems to prolong the life of reloaded shells.

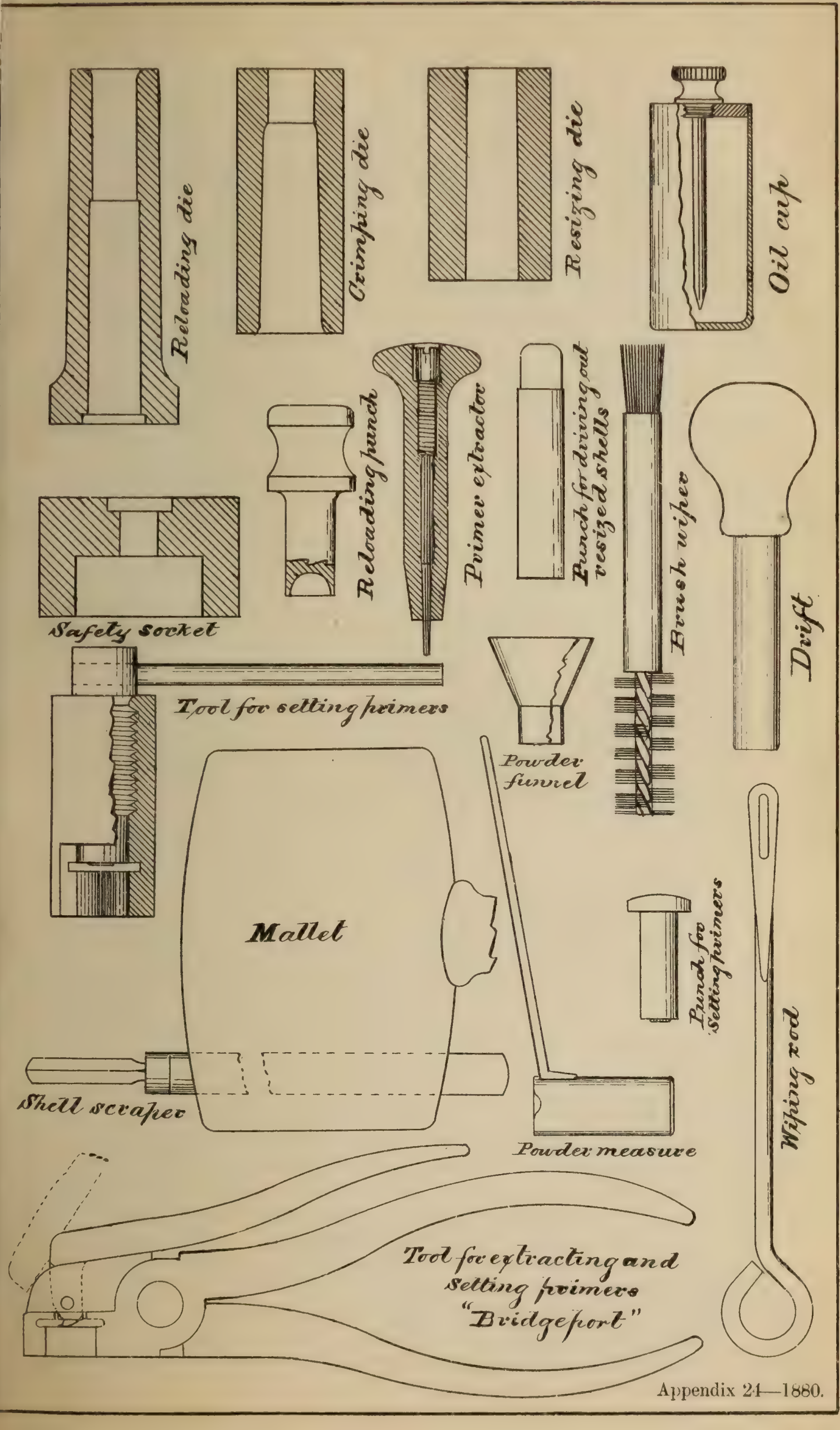
The tendency of the shells to tear apart appears to be due to their unequal expansion in the chamber; the front end being thin is more quickly expanded, and in the absence of the lubricant is held by pressure and friction against the walls of the chamber, while the thick rear end of the shell is forced backward by the pressure of the gases.

As a rule sufficient lubricant from the bullet finds its way into the chamber to answer all purposes.

These tools are made as simple and strong as possible. Some of them, particularly the dies and punches, require to be used with great care, so as not to injure their surfaces or alter their dimensions, where such would affect the cartridge.

They are cheap, durable, and quite rapid in operation if the work be divided among several operators or be done by one person performing each operation separately on a number of shells.

In case tools are broken or disabled they should be sent to the Frankford Arsenal, Philadelphia, so that perfect ones may be issued to replace them.


Reloading die
Crimping die
Resizing die
Oil cup
Reloading punch
Primer extractor
Punch for driving out resized shells
Brush wiper
Drift
Safety socket
Tool for setting primers
Powder funnel
Mallet
Punch for setting primers
Wiping rod
Shell scraper
Powder measure
Tool for extracting and setting primers "Bridgeport"

APPENDIX 25.

EXTREME RANGES OF MILITARY SMALL-ARMS.

(Four plates.)

NATIONAL ARMORY,
Springfield, Mass., May 17, 1879.

To the CHIEF OF ORDNANCE *U. S. A., Washington, D. C.:*

SIR: Agreeably to your instructions of February 11, 1879, I have the honor to submit herewith Captain Greer's report of his experiments with the Springfield and Martini-Henry arms and their ammunition.

The comparison relates principally to the firing qualities of the arms and the weight of ammunition used in each.

The experiments show that the recoil of the Springfield carbine is no greater than that of the rifle, both firing the rifle cartridge of 70 grains of powder. As this result has been repeatedly obtained I have every confidence in its correctness, although not exactly in accordance with the generally received opinion in the Army on this subject.

Attention is called to the article in the "Journal of the Royal United Service Institution," referred to by Captain Greer, as it contains many interesting facts of the late Turko-Russian war, showing the great effect that can be produced by small-arm fire at a distance of a mile and upwards.

Captain Greer's report shows that the Springfield rifle with its light-weight ammunition is effective to a distance of at least 1½ miles.

Very respectfully, your obedient servant,

J. G. BENTON,
Lieutenant-Colonel of Ordnance, Commanding.

NATIONAL ARMORY,
Springfield, Mass., May 9, 1879.

SIR: In accordance with your instructions of March 17, 1879, I have the honor to submit herewith results of comparative trials of the Springfield and Martini-Henry rifles, cal. 0″.45.

The latter arm with a supply of ammunition—wrapped metal cartridges—was recently presented by the British Government, and is a type of the service-gun in its latest form.

The rifles were tested in comparison for initial velocity, recoil, power—as shown by penetration in white pine—accuracy, and flatness of trajectory. In regard to accuracy it will be seen that the Springfield did better than the Martini with the exception of one of the targets at 1,000 yards. A strong wind blowing when that target was made had greater effect on the light-service bullets than on the Martini with its 75 grains more lead. The other target was made in calm weather. In all the other points the superiority of the Springfield was manifest except in the single one of penetration; but as tests made in comparing it with the Peabody-Martini showed that it gave a penetration of nearly two inches at about one mile, or sufficient to disable, if not to kill, a man at that range (see Table VII), it would seem hardly necessary to increase

its power and consequently its recoil, especially as the line of the Army has objected to any increase of the latter. It is extremely probable that the lesser penetration of the Springfield is due to the grooves on the bullet, which, by their shoulders, form lines of resistance, enabling the wood to exert a greater retarding effect. This was shown in comparing the carbines where the velocity of the Springfield bullet was 1,320 feet and that of the Martini, which was but 5 grains heavier, 1,140 feet. The slight difference in weight could not have neutralized the difference in velocity by giving greater penetration. (See Table III, tests of carbines.) It should be borne in mind, however, that shooting at animate objects is not usually through wood, but air. The objection to increasing the power of the arm is not wholly confined to that of recoil. The weight of the ammunition is an important consideration. In No. XCVIII, volume XXII, Journal of the Royal United Service Institution, will be found an interesting article entitled "Lessons from the late War," in which the number and weight of cartridges carried, long-range firing, and the method of aiming is discussed. In this article it is stated that the Turks fired with effect at 2,500 yards, and that they carried from 100 to 150 cartridges in belts and in pockets on the breasts of their coats. One hundred rounds of Martini rifle cartridges weigh nearly two pounds and two ounces more than the same number of United States service cartridges. This additional weight is highly objectionable unless necessary, and all experience plainly indicates that it is not. If, however, an increase in power is considered desirable, it will be seen by the closing tables of this report that it may be readily made by simply increasing the charge of powder without the necessity of enlarging the chamber for a longer shell, although the latter would be preferable, as the pressure on the bore would be diminished.

With the 85-grain charge of powder, the weight of the bullet remaining the same, the high velocity obtained, 1,480.5 feet, gives a much flatter trajectory with largely increased dangerous space.

Your instructions also contemplated a comparison of the Springfield and Martini-Henry carbines, the latter, with its ammunition, having been presented by the British Government at the same time as the rifle.

The remarks already made in regard to the rifles seem to apply equally well to the carbines. If the Springfield with its regular cartridge containing but 55 grains of powder is not so powerful an arm as the Martini, it is only necessary to refer to the fact that the Ordnance Department is on record as being in favor of abolishing that cartidge entirely and using the rifle cartridge with its 70 grains of powder instead.

In truth, this question was submitted to the troops serving in the extreme western departments, and the decision was, by a large majority, against it, on the ground of too great recoil with the heavier cartridge.

Examination of the tables, however, shows that the recoil is no greater than with the Martini. If, then, the English and Turkish soldiers can endure it ours should do so as well. As a matter of fact, *the recoil of the carbine with the rifle cartridge is no greater than the recoil of the rifle with the same cartridge.* This was shown by the dynamometer reading, a mean of five shots being taken. Being so contrary to generally accepted opinions, the trial was repeated with precisely the same result. (See Table VII, tests of carbines.) The explanation undoubtedly is, that though the carbine is 1 lb. and 6 ozs. lighter than the rifle, the velocity obtained with it is much less than with the longer barrel, and the recoil is dependent both on the weight and velocity of the bullet as well as the weight of the arm, the quantity of motion of the gun being equal to that of the projectile.

There seems to be no good reason why the cavalry should not endure as great a recoil as the infantry.

The weights of the arms used are as follows:

	lbs.	ozs.
Springfield rifle	9	2
Bayonet and scabbard	1	2
Total	10	4
Martini Henry rifle	8	13
Bayonet and scabbard	1	7
Total	10	4
Springfield carbine	7	12
Martini-Henry carbine	7	7

The barrel of the Martini-Henry rifle is 1.25 inch longer than that of the Springfield, and of the carbine 0.75 *inch shorter* than the Springfield.

The only novelty observed on the Martini is a brass cap for the protection of the front sight. The rear sight is protected by a leather strap buttoned over it.

The carbine barrel is stocked its whole length and has a full-length ramrod.

Appended will be found a table containing data relating to the small-arms of the leading nations of the world.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A.

To the COMMANDING OFFICER, *National Armory.*

Results of tests with rifle.

I.—VELOCITIES.

Rifles.	Weight of powder.	Weight of ball.	Number of shot.	Velocities by— Le Boulengé chronograph.	Velocities by— Benton electro-ballistic.
Springfield	70 grains.	405 grains.	1	1371.0 feet.	1375.1 feet.
			2	1373.0 feet.	1381.1 feet.
			3	1367.1 feet.	1372.0 feet.
			4	1358.3 feet.	1362.1 feet.
			5	1366.1 feet.	1372.1 feet.
			Mean.	1367.1 feet.	1372.4 feet.
			Mean by both machines.	1369.7 feet.	
Martini-Henry	85 grains.	480 grains.	1	1261.2 feet.	1262.0 feet.
			2	1237.7 feet.	1247.9 feet.
			3	1250.5 feet.	1252.9 feet.
			4	1240.7 feet.	1258.0 feet.
			5	1258.3 feet.	1258.0 feet.
			Mean.	1249.7 feet.	1255.8 feet.
			Mean by both machines.	1252.8 feet.	

Results of tests with rifles—Continued.

II.—RECOIL.

Rifle.	Weight of powder.	Weight of ball.	Number of shot.	Recoil.
Springfield	70 grains.	405 grains.	1	9.5 foot-pounds.
			2	10 foot-pounds.
			3	10 foot-pounds.
			4	10 foot-pounds.
			5	10 foot-pounds.
			Mean.	9.9 foot-pounds.
Martini-Henry	85 grains.	480 grains.	1	13 foot-pounds.
			2	12.5 foot-pounds.
			3	12.75 foot-pounds.
			4	12.5 foot-pounds.
			5	13 foot-pounds.
			Mean.	12.75 foot-pounds.

III.—PENETRATION.

Rifle.	Weight of powder.	Weight of ball.	Number of shot.	100-yards range. Inches in white pine.	300-yards range. Inches in white pine.
Springfield	70 grains.	405 grains.	1	11.5	10.5
			2	11.75	11
			3	11.25	10.25
			4	11.50	11
			5	12	11
			Mean.	11″.6	10.75
Martini-Henry	85 grains.	480 grains.	1	14.25	14.25
			2	14.25	15
			3	14.25	14
			4	15.25	14
			5	15.25	14
			Mean.	14.65	14.25

IV.—ACCURACY.

Rifles.	300 yards.			500 yards.			1,000 yards. First target.*			1,000 yards. Second target.		
	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.	Mean horizontal deviation.	Mean vertical deviation.	Mean absolute deviation.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Springfield	2.36	2.64	3.54	6.3	5.6	8.42	14.8	27	30.8	9.23	16.8	19.1
Martini-Henry	3.08	2.8	4.16	11.6	6.1	13.1	18.7	16.9	25.2	10.9	14.55	18.2
	Targets of 10 shots each. Shoulder and muzzle rest.						Targets of 20 shots each.					

*Strong and variable wind.

Results of tests with rifles—Continued.

IV.—ACCURACY—Continued.

(As recorded by Creedmoor system.)

Rifle.	300 yards.	500 yards.	1,000 yards.	
			First target.*	Second target.
	Possible 50.	Possible 50.	Possible 100.	Possible 100.
Springfield	47	48	51	79
Martini-Henry	40	37	56	68
	Shoulder and muzzle rest.			

* Strong and variable wind.

V.—VELOCITIES.

Rifle.	Weight of powder.	Weight of ball.	Velocities. Muzzle.	100 yards.	200 yards.	300 yards.	400 yards.	500 yards.	600 yards.	700 yards.	800 yards.
	G s.	Grs.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Springfield	85	405	1480. 5	1265. 8	1105. 5	982. 4	882. 1	801. 1	733. 9	676. 9	628. 2
Springfield	70	405	1350	1171. 3	1034. 3	926. 2	838. 4	765. 8	704. 8	652. 8	607. 9
Martini-Henry	85	480	1252. 8	1120. 3	1013. 1	924. 4	850. 4	787. 2	732. 7	685. 3	643. 7

Rifle.	Velocities. 900 yards.	1000 yards.	1100 yards.	12000 yards.	1300 yards.	1400 yards.	1500 yards.	1600 yards.	1700 yards.	1800 yards.	1900 yards.	2000 yards.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Springfield	586. 1	549. 2	516. 7	487. 8	462. 1	438. 8	417. 7	398. 7	381. 3	365. 3	350. 7	337. 2
Springfield	568. 9	534. 5	504. 1	476. 8	453. 6	430. 5	410. 5	392. 3	375. 7	360. 4	346. 3	333. 2
Mantini-Henry	606. 8	573. 9	544. 5	517. 8	493. 7	471. 7	451. 6	433. 1	416. 1	400. 4	385. 8	372. 2

VI.—ANGLES OF ELEVATION.

Rifle.	Weight of powder.	Weight of ball.	Angles of elevation. 100 yards.	200 yards.	300 yards.	400 yards.	500 yards.	600 yards.	700 yards.
	Grs.	Grs.	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Springfield	85	405	9 9 29. 2	0 19 50. 5	0 32 48. 7	0 47 31. 5	1 3 42. 5	1 21 9. 1	1 39 44. 2
Springfield	70	405	0 10 25. 9	0 23 53	0 38 24. 7	0 55 24. 1	1 14 4. 7	1 34 14. 5	1 55 43. 1
Martini-Henry	85	480	0 11 47. 2	0 25 50. 5	0 41 58. 8	0 59 58. 7	1 19 41. 1	1 40 56. 5	2 3 14. 5

Results of tests with rifles—Continued.

VI.—ANGLES OF ELEVATION—Continued.

Rifle.	Angles of elevation.							
	800 yards.	900 yards.	1000 yards.	1100 yards.	1200 yards.	1300 yards.	1400 yards.	1500 yards.
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
Springfield	1 59 18. 5	2 19 42. 9	2 40 53	3 2 45. 6	3 25 14. 6	3 48 11	4 9 5. 4	4 35 33. 6
Springfield	2 18 23. 5	2 42 1. 7	3 6 37. 5	3 31 58	3 58 8. 5	4 24 34	4 52 12. 4	5 20 4. 5
Martini-Henry	2 27 30. 1	2 52 29. 8	3 18 35. 8	3 45 35. 4	4 13 27. 1	4 42 6. 6	5 11 27. 6	5 41 23. 7

Angles computed in the following manner,* the initial velocity V having been instrumentally determined:

Remaining velocity at any point .... $= V' = \frac{V}{1 + c v x}$

Mean velocity throughout a given range, x .... $= V'' = \frac{V + V'}{2}$

Time of flight of bullet throughout a given range, x .... $= t = \frac{x}{V''}$

Space fallen through by bullet in time t, due to gravity .... $= S = \frac{gt^2}{2} = \frac{gx^2}{2V'^2}$

Tangent of angle of elevation A .... $= \frac{S}{x} = \frac{gx}{2V''}$

$\text{Log tan A} = \log \frac{g}{2} + \log X + \log R - 2 \log V'' = \log 16.08 + \log X + 10 - 2 \log V'' = 11.206286 + \log X - 2 \log V''.$

$R =$ radius of logarithmic tables.

$C = \frac{b\,r^2}{w}$ in which b varies from .000063 to .000060 for velocities of from 1500 to 1050 feet.

$r =$ radius of projectile in feet, and

$w =$ weight of projectile in pounds.

VII.—VELOCITIES AND PENETRATIONS.

(For determining probable power of Springfield rifle at 2,500 yards.)

Rifle.	Weight of powder.	Weight of ball.	Range.	No. of shot	Velocities at 12½ feet from muzzle by Le Boulengé chronograph.	Penetrations in white pine.
Springfield ..	9 grains.....	405 grains...	12½ feet	1	278. 2 feet	1 inch.
				2	299. 8 feet	1 inch.
				3	282. 1 feet.......	1 inch.
				4	Lost	1 inch.
				5	273. 1 feet.	1 inch.
				Mean.	283. 3 feet.	1 inch.
Springfield ..	10 grains....	405 grains...	12½ feet	1	436. 7 feet	2. 25 inches.
				2	378. 7 feet	1. 4 inches.
				3	403 feet	2 inches.
				4	423 feet	2. 25 inches.
				5	420. 7 feet	2. 25 inches.
				Mean.	412. 4 feet.	2. 04 inches.
Springfield ..	70 grains....	405 grains...	1,670 yds...	....	†380. 7 feet	‡1. 87 inches.
			2,500 yds...	....	†280 feet	§1 inch.

* Approximately correct only, feet very closely so for ranges up to 1,000 yards.
† Computed.
‡ Actual penetration; mean of several shots.
§ Probable penetration, as seen by comparing velocity with that obtained with 9 grains of powder.

Results of tests with rifles—Continued.

VIII.—VELOCITIES AND ENERGIES—AT MUZZLE.

Rifle.	Weight of powder.	Weight of ball.	No. of shot.	Velocities at muzzle by— Le Boulengé chronograph.	Velocities at muzzle by— Benton electro-ballistic.	Energies at muzzle.
Springfield	85 grains*.	405 grains†	1	1,490.6 feet	1,492.7 feet	
			2	1,458.2 feet	1,471.7 feet	
			3	1,478.8 feet	Lost.	
			4	1,483.7 feet	1,478.7 feet	
			5	1,483.7 feet	1,486 feet	
			Mean.	1,479 feet	1,482.3 feet	
			Mean by both machines.	1,480.5 feet		1,971.7 ft.-lbs.
Martini-Henry	85 grains	480 grains.	1	1,261.2 feet	1,262 feet	
			2	1,237.7 feet	1,247.9 feet	
			3	1,250.5 feet	1,252.9 feet	
			4	1,240.7 feet	1,258 feet	
			5	1,258.3 feet	1,258 feet	
			Mean.	1,249.7 feet	1,255.8 feet	
			Mean by both machines.	1,252.8 feet		1,673.3 ft.-lbs.

AT 300 YARDS.

Rifle.	Weight of powder.	Weight of ball.	Velocities.‡	Energies.	No. of shot.	Penetration in white pine.
Springfield	85 grains*	405 grains†.	982.4 feet.	868.1 foot-pounds.	1	12.25 inches.
					2	12 inches.
					3	11.75 inches.
					4	12 inches.
					5	12.25 inches.
					Mean.	12.05 inches.
Martini-Henry.	85 grains	480 grains.	924.4 feet.	911 foot-pounds.	1	14.25 inches.
					2	15 inches.
					3	14 inches.
					4	14 inches.
					5	14 inches.
					Mean.	14.25 inches.

* Hazard service musket, sifted to exclude grains larger than 0″.0475.
† One-twelfth tin, instead of $\frac{1}{16}$, as in service.
‡ Velocities computed by formula—

$v^1 = \frac{V}{1+cVx}$ (See "Text Book on Construction and Manufacture of Rifled Ordnance," and works of Professor Bashforth), in which

v^1 = remaining velocity;
V = initial velocity;
x = range = 300 yards = 900 feet.
$c = \frac{br^2}{W}$, in which $b = .0000006286$ and $.00006134$ for Springfield and Martini respectively.
$r = \frac{0.225}{12}$ feet.
$W = \frac{405}{7000}$ pounds, and $\frac{480}{7000}$ pounds.

Results of tests with carbines.

I.—VELOCITIES.

Carbine.	Weight of powder.	Weight of ball.	No. of shot.	Velocities by— Le Boulengé chronograph.	Benton electro-ballistic.
Springfield	55 grains	405 grains.	1	1, 125. 5 feet.	1, 132. 1 feet.
			2	1, 147. 1 feet.	1, 150 feet.
			3	1, 133. 9 feet.	1, 137. 2 feet.
			4	1, 116. 2 feet.	1, 120. 5 feet.
			5	1, 119 2 feet.	1, 121. 5 feet.
			Mean.	1, 128. 4 feet.	1, 132. 2 feet.
			Mean by both machines.	1, 130. 3 feet.	
Springfield	70 grains	405 grains.	1	1, 325. 9 feet.	1, 330. 9 feet.
			2	1, 314. 2 feet.	1, 319 feet.
			3	1, 313. 2 feet.	1, 318. 5 feet.
			4	1. 314. 2 feet.	1, 322. 4 feet.
			5	1, 316. 1 feet.	1, 319. 5 feet.
			Mean.	1, 316. 7 feet.	1, 332. 1 feet.
			Mean by both machines.	1, 319. 4 feet.	
Martini-Henry	70 grains	410 grains.	1	1, 143. 7 feet.	1, 148. 2 feet.
			2	1, 138. 3 feet.	1, 139. 4 feet.
			3	1, 134. 8 feet.	1, 138. 9 feet.
			4	1, 131. 9 feet.	1, 135. 2 feet.
			5	1, 146. 1 feet.	1, 150 feet.
			Mean	1, 138. 9 feet.	1, 142. 3 feet.
			Mean by both machines.	*1, 140. 6 feet.	

* The low velocity of the Martini, as compared with the Springfield using the same charge, is due to ts larger shell, the powder undergoing no compression whatever, 70 grains occupying the same space as 85 grains in the rifle cartridge, while in the Springfield rifle cartridge the powder undergoes a compression of from three to four-tenths of an inch in the length of the shell.

II.—RECOIL.

Carbine.	Weight of powder.	Weight of ball.	Number of shot.	Recoil.
Springfield	55 grains.	405 grains.	1	7. 5 foot-pounds.
			2	7. 5 foot-pounds.
			3	7. 5 foot-pounds.
			4	7. 5 foot-pounds.
			5	7. 5 foot-pounds.
			Mean.	7. 5 foot-pounds.
Springfield	70 grains.	405 grains.	1	10 foot-pounds.
			2	10 foot-pounds.
			3	10 foot-pounds.
			4	9. 5 foot-pounds.
			5	10 foot-pounds.
			Mean.	9. 9 foot-pounds.
Martini-Henry	70 grains.	410 grains.	1	10 foot-pounds.
			2	10 foot-pounds.
			3	10 foot-pounds.
			4	9. 5 foot-pounds.
			5	10 foot-pounds.
			Mean.	9. 9 foot-pounds.

Results of tests with carbines—Continued.

III.—PENETRATION.

Carbine.	Weight of powder.	Weight of ball.	Number of shot.	100 yards range. Inches in white pine.	300 yards range. Inches in white pine.
Springfield	55 grains.	405 grains.	1	11.5	8.25
			2	10.5	9.25
			3	10.25	8.5
			4	10.5	9
			5	11	9
			Mean.	10.75	8.8
Springfield	70 grains.	405 grains.	1	11.75	9.75
			2	11.5	9.25
			3	12.5	9.25
			4	12.25	10
			5	12	9
			Mean.	12	9.45
Martini-Henry	70 grains.	410 grains.	1	11.75	10.25
			2	11.25	10
			3	12	10.25
			4	12.25	10.25
			5	12	10.25
			Mean.	11.85	10.2

IV.—ACCURACY.

Carbine.	Weight of powder.	Weight of ball.	100 yards. Mean horizontal deviation.	100 yards. Mean vertical deviation.	100 yards. Mean absolute deviation.	300 yards. Mean horizontal deviation.	300 yards. Mean vertical deviation.	300 yards. Mean absolute deviation.
			Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Springfield	55 grains.	405 grains.	1.28	1.44	1.93	1.92	3.1	3.64
Springfield	70 grains.	405 grains.	0.7	1.28	1.45	3.3	3.1	4.52
Martini-Henry	70 grains.	410 grains.	1.0	1.08	1.47	4.72	2.12	5.18

Targets, 10 shots each. Shoulder and muzzle rest.

Carbine.	Weight of powder.	Weight of ball.	500 yards. Mean horizontal deviation.	500 yards. Mean vertical deviation.	500 yards. Mean absolute deviation.	800 yards. Mean horizontal deviation.	800 yards. Mean vertical deviation.	800 yards. Mean absolute deviation.
			Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
Springfield	55 grains.	405 grains.	6.2	5.92	8.57	11.04	19.4	22.3
Springfield	70 grains.	405 grains.	5.62	2.76	6.26	9.28	23.4	25.1
Martini-Henry	70 grains.	410 grains.	5	7.92	9.36	10.3	14.32	17.7

Targets, 10 shots each. Shoulder and muzzle rest.

Results of tests with carbines—Continued.

IV.—ACCURACY—Continued.

(As recorded by Creedmoor system.)

Carbine.	Weight of powder.	Weight of ball.	100 yards. Possible 50.	300 yards. Possible 50.	500 yards. Possible 50.	800 yards. Possible 50.
Springfield	55 grains.	405 grains.	50	45	47	37
Springfield	70 grains.	405 grains.	50	44	48	39
Martini-Henry	70 grains.	410 grains.	43	41	47	31

Targets, 10 shots each. Shoulder and muzzle rest.

V.—VELOCITIES.

Carbine.	Weight of powder.	Weight of ball.	Velocities. Muzzle.	100 yards.	200 yards.	300 yards.	400 yards.
	Grs.	*Grs.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Springfield	55	405	1, 130. 3	1, 005	904. 7	822. 6	754. 2
Springfield	70	405	1, 320	1, 149. 1	1, 017. 4	912. 8	827. 7
Martini-Henry	70	410	1, 140. 6	1, 014. 3	913. 3	830. 5	761. 5

Carbine.	Velocities. 500 yards.	600 yards.	700 yards.	800 yards.	900 yards.	1,000 yards.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Springfield	696. 2	646. 5	603. 5	565. 8	532. 5	503
Springfield	757. 1	697. 6	646. 8	602. 9	564. 5	530. 7
Martini-Henry	703. 1	653	609. 5	571. 5	538	508. 1

VI.—ANGLES OF ELEVATION.

Carbine.	Weight of powder.	Weight of ball.	Angles of elevation. 100 yards.	200 yards.	300 yards.	400 yards.
	Grs.	*Grs.*				
Springfield	55	405	0° 14′ 33″. 5	0° 32′ 2″	0° 52′ 11″. 5	1° 14′ 41″. 8
Springfield	70	405	0° 10′ 53″. 2	0° 24′ 17″. 1	0° 39′ 55″	0° 57′ 31″
Martini-Henry	70	410	0° 14′ 17″. 4	0° 31′ 26″. 9	0° 51′ 13″. 4	1° 13′ 20″. 2

Carbine.	Angles of elevation. 500 yards.	600 yards.	700 yards.	800 yards.	900 yards.	1,000 yards.
Springfield	1° 39′ 24″. 2	2° 5′ 59″. 2	2° 34′ 19″. 8	3° 4′ 16″. 4	3° 35′ 35″. 4	4° 8′ 8″. 5
Springfield	1° 16′ 51″. 3	1° 37′ 43″. 8	1° 59′ 59″. 7	2° 23′ 27″. 2	2° 47′ 59″. 6	3° 13′ 29″. 1
Martini-Henry	1° 37′ 32″. 2	2° 3′ 40″	2° 31′ 31″. 5	3° 0′ 53″. 5	3° 31′ 36″. 8	4° 3′ 39″. 6

Results of tests with carbines—Continued.

VII.—RECOIL.*

No. of shot.	Springfield rifle.	Springfield carbine.	Martini-Henry carbine.	
	Rifle cartridges.			
1	9.5 foot-pounds.	10 foot-pounds.	10 foot-pounds.	First trial, April 10, 1879.
2	10 foot-pounds.	10 foot-pounds.	10 foot-pounds.	
3	10 foot-pounds.	10 foot-pounds.	10 foot-pounds.	
4	10 foot-pounds.	9.5 foot-pounds.	9.5 foot-pounds.	
5	10 foot-pounds.	10 foot-pounds.	10 foot-pounds.	
Mean	9.9 foot-pounds.	9.9 foot-pounds.	9.9 foot-pounds.	
1	9.75 foot-pounds.	9 foot-pounds.	....	Second trial, April 26, 1879.
2	9.75 foot-pounds.	9.5 foot-pounds.		
3	10 foot-pounds.	10 foot-pounds.		
4	10 foot-pounds.	10 foot-pounds.		
5	7.5 foot-pounds.	10 foot-pounds.		
Mean	9.8 foot-pounds.	9.7 foot-pounds.		

* For comparing Springfield rifle and carbine when using the rifle cartridge.

On page 30, "Description, etc., of the Springfield Rifle and Carbine," the recoil of the rifle is given as 174 pounds. It should be stated that this result was obtained by the use of a dynamometer in which a weighed spring was compressed in a manner similar to that of the ordinary spring-balance.

Owing to the slight resistance the gun experienced during the first part of its backward motion it moved with a considerable velocity, and compressed the spring by its momentum rather than by a simple pressure due to weight. In order to overcome this, it was suggested by Captain Prince, Ordnance Department, that the spring be given an initial compression of, say, 50 pounds, before the butt of the gun was placed in contact with it. By this means the reading was at once reduced to about 100 pounds. But as the method of measuring statically a recoil which was dynamic in its nature, owing to the motion of the gun, gave varying results for the same charge, due to variations in the springs employed, it was proposed by Lieutenant Mètcalfe, Ordnance Department, to express the *work* of recoil in foot-pounds, a method which eliminates the error before referred to, and this method has been adopted.

The results now obtained, it is thought, can be relied on.

DATA RELATING TO THE SMALL-ARMS OF THE LEADING NATIONS OF THE WORLD

Nation.	United States of America.	England and Turkey.
Arm.	Springfield.	Martini-Henry.
Weight of rifle without bayonet......	9 pounds 1.6 ounce............	8 pounds 12 ounces.
Weight of rifle with bayonet.........	9 pounds 13 ounces...........	9 pounds 12 ounces.
Length of rifle without bayonet....	4 feet 3.9 inches...............	4 feet 1.5 inch.
Length of rifle with bayonet.........	5 feet 9.8 inches...............	5 feet 11.5 inches.
Caliber across the lands.............	.45 inch	.45 inch.
Inclination of grooves................	1 turn in 22 inches	1 turn in 22 inches.
Number of grooves.....................	3....................................	7.
Extreme graduation of sight.........	1,600 yards.......................	1,400 yards.
Weight of bullet.......................	405 grains........................	480 grains.
Weight of powder charge.............	70 grains.........................	86 grains.
Weight of cartridge complete........	611 grains........................	766½ grains.

DATA RELATING TO THE SMALL-ARMS OF THE LEADING NATIONS OF THE WORLD—Continued.

VELOCITIES AND ENERGIES.*

Ranges......yards.	Muzzle.	1,000	2,000	2,500	Muzzle.	1,000	2,000	2,500
Velocities......feet.	1,350	534.5	333.2	280	1,252.8	573.9	372.2	316.2
Energies......ft.-lbs.	1,639.4	257	99.9	70.5	1,673.3	372.2	147.7	106.6

Nation.	† France.	Russia.
Arm.	Gras-Chassepot.	Mauser.
Weight of rifle without bayonet	9 pounds 4 ounces	9 pounds 4 ounces.
Weight of rifle with bayonet	10 pounds 8 ounces	9 pounds 12 ounces.
Length of rifle without bayonet	4 feet 3 inches	4 feet 2.38 inches.
Length of rifle with bayonet	5 feet 11 inches	5 feet 10.38 inches.
Caliber across the lands	.433 inch	.42 inch.
Inclination of grooves	1 turn in 21.66 inches	1 turn in 20 inches.
Number of grooves	4	6.
Extreme graduation of sight	1,968 yards	1,200 yards.
Weight of bullet	386 grains	368 grains.
Weight of powder charge	81 grains	77 grains.
Weight of cartridge complete	676 grains	600 grains.

VELOCITIES AND ENERGIES.

Ranges......yards.	Muzzle.	1,000	2,000	2,500	Muzzle.	1,000	2,000	2,500
Velocities......feet.	1,430	553.5	343.2	288.4	1,384.9	552.6	345.2	290.6
Energies......feet.-lbs.	1,753.1	262.7	101	71.3	1,567.6	249.6	97.4	69

Nation.	* Prussia.	*Austria and Hungary.
Arm.	Berdan.	Werndl.
Weight of rifle without bayonet	9 pounds 10 ounces	9 pounds 3 ounces.
Weight of rifle with bayonet	11 pounds 5 ounces	10 pounds 14 ounces.
Length of rifle without bayonet	4 feet 5 inches	4 feet 2 inches.
Length of rifle with bayonet	6 feet	5 feet 9 inches.
Caliber across the lands	.433 inch	.421 inch.
Inclination of grooves	1 turn in 21.66 inches	1 turn in 28.74 inches.
Number of grooves	4	6.
Extreme graduation of sight	1,750 yards	1,161 yards.
Weight of bullet	386 grains	371 grains.
Weight of powder charge	77 grains	77 grains.
Weight of cartridge complete	660 grains	656 grains.

VELOCITIES AND ENERGIES.

Ranges......yards.	Muzzle.	1,000	2,000	2,500	Muzzle.	1,000	2,000	2,500
Velocities......feet.	1,410	551.2	342.6	288.1	1,437	559.9	347.7	292.3
Energies......ft.-lbs.	1,704.4	254.5	100.6	71	1,709.4	258.3	99.6	70.4

*Computed.

† Musketry instruction and long-range infantry fire in Austria, France, and Prussia.—No. XCVII, Vol. 22, Journal of the Royal United Service Institution.

NATIONAL ARMORY,
Springfield, Mass., January 15, 1880.

CHIEF OF ORDNANCE, U. S. A., *Washington, D. C.:*

SIR: I have the honor to forward herewith two reports by Captain John E. Greer, Ordnance Department, of experiments made by him at Sandy Hook in the months of October and November, 1879. These experiments were made by your approval, and for the purpose of determining the extreme ranges, &c., of certain military small-arms. It is thought that much of the data given in Captain Greer's reports will be

found to be new, and especially useful in increasing the range and efficiency of the service arms.

I hope soon to submit reports of further experiments, which are now being made at this armory, to determine what changes, if any, are necessary in the present system of rifling and form of cartridge to make the results at Sandy Hook of practical use to the service.

Very respectfully, your obedient servant,

J. G. BENTON,
Col. of Ordnance, Com'd'g.

LONG-RANGE FIRING.

NATIONAL ARMORY,
Springfield, Mass., October 15, 1879.

SIR: In my report of May 9, 1879, on the comparative trials of the Springfield and Martini-Henry rifles, the penetration of the former in white pine at 2,500 yards' range was given as one inch. This was determined by computing the remaining velocity of the bullet at that distance by the formula employed by Capt. W. H. Noble, R. A., in computations of this nature, which, it may be stated, gives results not differing materially from those obtained by the application of Prof. Bashforth's formula, as given in his "Motion of Projectiles," and then preparing cartridges with various charges of powder and testing until a muzzle velocity was obtained equal to the computed velocity at 2,500 yards. Similar cartridges, on being fired, gave a muzzle penetration of one inch, and hence it was inferred that the penetration at 2,500 yards was also one inch.

Since the date of that report an opportunity of verifying this computation by actual firing has been afforded me at the Ordnance Proving Ground, Sandy Hook, N. J.; also of further testing the rifles mentioned, and that recently prepared at this armory and issued to the teams representing the Departments of the Atlantic and Pacific, known as the Springfield long-range rifle. Weight of powder charge, 80 grains; weight of ball, 500 grains.

By trials at this armory, the penetration of the service bullet at 1,669 yards, the longest range attainable, was found to be 1.87 inch.

It was proposed to extend the trials to 2,000 and 2,500 yards with the service rifle, and with the Martini-Henry and Springfield long-range to 3,000 and 3,500 yards, if the results at the shorter ranges were satisfactory.

A leaf to the rear sight several inches in length was prepared by my direction in order to get the necessary elevation up to 2,500 yards. A combination of the buck-horn slide of the regular sight and a screw at the bottom of the leaf afforded means of correcting for wind, drift, &c. As the range was along the water's edge it was hoped that there would be but little difficulty in seeing the shots strike the sand, or at least in finding the holes made by them, in order to properly direct the marksmen. For this purpose a small hole was dug in the sand 30 or 40 feet in front of the right edge of the target, the sand being thrown to the rear. Two thicknesses of boards resting on it and projecting over the front were lightly covered with sand, making a sort of bomb-proof for myself and an assistant, from which we could observe the shots. The firing was done by Mr. R. T. Hare, of this armory, who has the enviable distinction, so far as is known, of being the only person in the world

who has ever hit the "bull's-eye," 6 feet in diameter, at 2,500 yards with three different rifles, and who has ever fired at and hit so small a target as that described in this report at 3,200 yards. In comparison with this all other so-called "long-range firing" sinks into insignificance. The gun was held under the arm, a muzzle-rest only being used.

A telephone in the pit with us and another at the firing stand afforded constant communication, by which our labors were greatly facilitated. In fact, at the longer ranges this means of communication was indispensable, since an intervening elevation prevented flag signals being seen at the other end of the range. The target at 1,200 yards was 12 feet square and 3 inches thick, being made from 1-inch pine boards separated by cleats.

After some difficulty in getting the proper elevation and line, the rifles not being sighted, of course, for such a range, the target was hit several times with each of them. Though hit but a few times in comparison to the number of shots, the accuracy was wonderfully good in this much, that a hundred-foot circle on the ground contained all the shots fired under any particular elevation, and in this respect the service cartridge appeared a little superior to the others. In many instances, at all the ranges, bullets struck within 5 feet of each other.

The shot-holes of the service bullets in the target made an angle with its face of about 45°, the Martini somewhat greater, and the Springfield long-range materially so. The elevations required to reach the target, and the mean penetrations, are given in the following table.

Range, 2,000 *yards*.

Rifle.	Penetrations.	Elevations.
Springfield service	1. 5 inch.	11° 58′
Springfield long-range	Through 3-in. target.	8° 16′ 2″
Martini-Henry	Through 3-in. target.	9° 48′ 57″

The target, it will be seen, was not thick enough to stop the heavier bullets; it was therefore transferred 500 yards farther down the beach. As it was but 12 feet square and difficulty had been found in locating the shots at the shorter range, it was decided to extend its length to 44 feet by the use partly of pine, there being but a small quantity at hand, and partly of spruce boards, 16 feet long, each side of the original target, and also to raise the latter about 4 feet from the ground.

Immediately above the original target the height was increased 6 feet, making the target 22 feet high in the middle and 16 feet at the wings. That part of the target in line with the original was 2 inches, and all above and below 1 inch thick. The whole was nailed to spruce posts about 6 inches thick.

The target was hit five times with the service rifle in 70 rounds, once with the Martini in 80 rounds, and four times with the long-range Springfield in 30 rounds. On renewing the firing the next day it was hit once more with the long-range rifle and twice with the Martini.

The results at this range are given in the following table:

Range, 2,500 *yards*.

Rifle.	Penetrations.	Elevations.
Springfield service	1. 12 inch.	17° 08′ 16″
Springfield long-range	5. 25 inches.	10° 38′ 21″
Martini-Henry	2. 50 inches.	13° 20′ 18″

Of the long-range bullets three passed through the target and buried themselves several inches in the sand. One of the others passed through a 1-inch board and penetrated 3.75 inches into one of the posts to which the board was nailed. The other hit the 3-board target at a point over the cleats and passed clear through 5 inches of pine (3 boards and 2 separating cleats) and entered 0.75 of an inch in one of the posts.

The mean penetration of these two shots is given, as the target was not thick enough to stop the other bullets. Of the Martini balls, one passed through a part of the target 2 inches thick and fell down on the sand behind it; another passed through a 1-inch board and penetrated one of the posts 1 inch; the last hit the three-board target, passed through two boards, and penetrated the last one 0.5 of an inch.

The angle made by the shot-holes with the face of the target appeared to be about 40°, 45°, and 50° for the service, Martini, and long-range rifles respectively. Bullets of the various kinds were dug out of the sand within 45 feet of the target and directly behind it. This fact shows how great the angle of the trajectory at this range, and how extremely difficult to hit a target the size of the one used.

The target was then placed at 3,200 yards from the firer. This distance was selected partly because the target was seen better than at 3,000 yards, on account of a slight elevation between it and the marksman's position, and partly because the supply of Martini cartridges was becoming much reduced, a large number being expended in getting the proper elevation and direction, and it was feared there would not be enough for use at 3,000 and 3,500 yards. The range chosen was fortunate in this, that it was found to be the extreme for the Martini, for when the firer was instructed to increase his elevation the range decreased. On decreasing the elevation the range increased to a certain point. Still the majority of the Martini balls fell from 50 to 100 yards short, while the others did not go more than 25 yards beyond.

Over 300 Martini cartridges were fired, but the target was not hit. All but 20 of the cartridges at hand were fired, these being reserved for velocity tests. At this range the angle of fall was about 65° to 70°, judging from the holes in the moist sand. Bullets were found in the sand behind the target, 22 feet high, at a distance of only 35 feet. It was evident that they struck the sand end-on, as the points were always found rough and slightly bruised.

At 2,500 yards and under the bullets were bruised only on the under side of the point.

With the long-range Springfield the target was hit three times, once where it was one board and twice where it was two boards thick. In each case the bullet passed clear through and buried itself several inches in the sand. The angle of the shot-hole with the face of the target was about 30°, and the bullet in going through the two boards actually passed over 2.5 inches. Those shots that struck in the sand generally penetrated to a depth of from 8 to 10 inches, and sometimes more. In this respect they surpassed the Martini bullets, which did not often penetrate more than 6 inches. In trying to get the proper elevation the long-range bullets were thrown over 300 yards beyond the target, and then were dug out of the ground and found to have struck point-on. A few are submitted, showing how the grains of sand were driven into the points.

At the 2,000 and 2,500-yard range a cut was made in the sand several inches in length, and the bullet rarely penetrated more than 4 or 5 inches; but at 3,200 yards a round hole about 1.5 inches in diameter at the top was made by the bullets, which buried themselves almost vertically.

The penetrations at 3,200 yards and the necessary elevations are given in the table.

Range, 3,200 yards.

Rifle.	Penetrations.	Elevations.
Springfield long-range	2.5 inches + sand.	20° 51′ 37″
Martini-Henry	Failed to get on target.	26° 51′ 00″

The extreme penetration of neither arm was found at this range, but enough was developed to show that either would kill at any distance to which the bullets could be thrown. The penetration appears to fall off but slightly beyond 1,700 yards, as may be seen from the record with the service gun. This is owing partly to the velocity acquired by the bullet falling through the height due to increased elevation, compensating for the loss of that velocity originally imparted by the powder-gas. It was proposed to construct several targets nearly horizontal and continue the trials, but owing to the lack of suitable lumber the idea was abandoned. In this connection it should be stated that English authorities claim a greater initial velocity for the Martini—1,372 feet—than it has been possible to get here. The cartridges were received from England with the rifle, the whole being presented by the British Government. Unless the powder undergoes deterioration by the sea voyage, or from contact with the brass of the shell, it is difficult to reconcile the claims made with the record as given here by several machines for determining velocity, working independently of each other by separate circuits.

The following table shows velocities of cartridges, reserved from those used at Sandy Hook in these experiments:

Table.

Rifle.	Weight of powder.	Weight of ball.	No. of shots.	Velocities.*	
				Le Boulengé Chronograph.	Benton's Electro-Ballistic.
Springfield service	70 grains.	405 grains.	5	1,325.3 feet.	1,328.6 feet.
Springfield long-range	80 grains.	500 grains.	5	1,269.8 feet.	1,267.3 feet.
Martini-Henry	85 grains.	480 grains.	5	1,261.2 feet.	1,264.5 feet.

*Taken simultaneously on the two machines.

The Martini, it will be observed, though firing 5 grains more powder, of a quicker variety, and 20 grains less lead than the long-range Springfield, gives the lesser velocity. This is due to the fact that the powder undergoes no compression in the Martini shell, owing to its great capacity as compared with the charge, while the reverse is the case with the Springfield.

The results of this firing are such, it is thought, as to justify a reopening of the whole question whether it is more advisable to adopt a heavier charge, both of powder and lead, with the increased recoil and diminution of number of cartridges that can be carried, in order to reach an enemy at great ranges, as both the English and Turks have done, or with a lighter bullet and higher velocity attain a flatter trajectory and greater dangerous space at ranges under a thousand yards, as the United States, in company with the leading continental countries, have done.

Among the more remarkable features developed in these rather remarkable trials, was that of the ability of a good marksman to throw his shots in such close proximity to each other at the longest ranges, in many cases the ten of each group falling within a few feet of each other. Presupposing a knowledge of the distance and some means of observing effect of shot to correct elevation, it is evident that among even a small number of troops many would be struck.

Ordinarily a large amount of ammunition would be consumed in proportion to the execution done in the ranks of the enemy; still, if it were at hand it would probably be advisable to use it at the utmost ranges. This was done by the Turks in the late war with Russia, and with more decided effect than usually attended their efforts in other directions.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. Army.

To the COMMANDING OFFICER, NATIONAL ARMORY.

To Capt. W. S. Starring, Ordnance Department, in charge of the Ordnance Proving Ground at Sandy Hook, I am indebted for aid of men in constructing, and horses for hauling targets, use of telephones, &c., and to Messrs. Sinclair and Merchant, employés, for assistance in laying wires for and operating the latter, and also in locating position of falling shots.

LONG-RANGE FIRING.

NATIONAL ARMORY,
Springfield, Mass., November 13, 1879.

SIR: In accordance with your instructions to continue experiments in long-range firing, I returned to Sandy Hook, N. J., taking with me, in addition to the guns mentioned in my report of October 15, a Springfield long-range rifle, 18-inch twist, a Sharp's (Borchardt) military, and, for comparison with the Martini-Henry, Springfield service and experimental 18-inch twist carbines. I also took cartridges for the long-range guns prepared with both 70 and 80 grains of powder, the bullets in each case being patched and weighing 500 grains. In addition I had a limited supply of cartridges for the service rifle prepared in a manner entirely similar to the service cartridge, except that the bullet was lengthened so as to bring its weight up to 500 grains. The powder charge was 70 grains. Finally, I was provided with service-carbine cartridges.

The target was composed of ten smaller ones, 16′x12′, arranged in quincunx order (see Plate III), each making a small angle with the ground, its rear being raised but about 4 feet. The whole gave a front of 80 and a depth of 60 feet, including the open spaces. The five targets in front were two 1-inch boards, and the remaining five one board in thickness. A flag on a staff at the center of the target enabled the marksman to determine the position of the latter.

TIME OF FLIGHT OF BULLETS AS DETERMINED BY THE TELEPHONE.

Hitherto the accurate determination of the time of flight of small-arm projectiles has been practically impossible at long ranges, owing to our inability to see them strike, even when firing over water. The discovery of the telephone has opened up to us a simple as well as novel means

of obtaining the time desired, and has also afforded us the means of verifying the formulas by which these times were formerly deduced.*

In these experiments two telephones provided with Blake transmitters were used. One was placed within a few feet of the gun and left open to receive and transmit the sound of the discharge. The other was in the shelter-proof, which was but about thirty feet in front of the right edge of the target. A stop-watch beating fourths of a second was used in connection with it. The telephone being at the ear, the instant the sound of the discharge was received at the target the watch was started, and on the bullet striking was stopped.

A mean of a large number of observations, which rarely differed more than a quarter to a half of a second from each other, gave the time of flight.† Of course there is a slight delay in starting the watch, but this is neutralized by a similar one in stopping it. The times given may, therefore, be accepted as strictly correct. It is worthy of notice that the times vary on different days, being shortened by a rear and lengthened by a head wind.

The velocity of sound may be readily obtained with the telephone in the same manner. The time for the sound of the discharge passing through the air was always shown by the watch; but as it was not desirable for my purpose to stop the watch until the bullet reached the targets, these times were not taken. This, so far as I am aware, is the first attempt to utilize the telephone in experiments of this nature.

The angles of elevation for each gun at each range were taken by means of a quadrant with a stem entering the barrel. In addition the angles were computed from the triangle on the gun, the heights of front and rear sights used being known, and the distance, measured on the axis of the bore, between them.‡ It may be stated that the angles at the higher ranges differed materially when taken on different days, head and rear winds causing much greater variations than at short ranges, owing to the longer times the bullets were subject to their influence. Winds also affected the extreme range of the guns, especially of the service and other arms using light bullets.

In these trials more difficulty was experienced than before in locating the position of the falling shots on account of the roaring of the surf, which prevented their striking the sand being heard, and the heavy winds which, prevailing most of the time, drifted them more or less at all ranges.

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*NOTE BY CHIEF OF ORDNANCE.—The first use of the telephone in determining the time of flight of projectiles, both for small arms and cannon, was made at the Sandy Hook Proving Ground during the summer of 1879, under the supervision of Capt. W. S. Starring, United States Ordnance Department.

Captain Greer availed himself of this valuable application of the telephone in his important experiments for long ranges, made a few months after, and deserves the credit of having made practical use of it, as recorded in this report.

†This method was developed on my first visit to Sandy Hook in the following manner: At the long ranges, except when the wind was favorable, the discharge of the gun could not be heard at the target. The telephone was then employed to transmit the sound of the discharge. Observation as to the long interval that elapsed before the bullet struck led at once to the idea of timing it. Having no stop-watch, this was not done until my return for further trials.

‡On examination of the tables it will be seen that there are numerous anomalies in regard to angles, and, in a few instances, in the times of flight. These, as stated, are due partly to the effect of winds, and partly to the fact that at high ranges the slide on the sight could be run up or down an inch or more from the point which appeared to be suitable for reaching the target without sensible variation in the range. This is due to the great curvature of the trajectory, as is illustrated by the diagram. In case of further trials a fixed rest would probably aid in getting the angles accurately.

3,500 YARDS RANGE.

Firing was commenced at a range of 3,500 yards with the service rifle and cartridge, but the target was not reached. The 18-inch twist long-range Springfield was then taken up and 40 shots fired, seeking the necessary elevation and direction, when the target was hit once in a portion 2 boards thick. The bullet passed through and penetrated the sand to a depth of 6 inches. The other bullets entered the sand from 10 to 12 inches.

On repeating the firing a few days later similar results were obtained, together with the time of flight. The angle of elevation at the second trial was several degrees less than the first used. As there was comparatively little wind the last day, the angle then taken was probably the true one. A mean, however, was taken. The long-range rifle used in previous trials, 19⅝-inch twist, was fired at 3,500 yards, and with the exception that the bullets did not happen to hit the target, though falling all around it, the results obtained, so far as penetration in sand is concerned, were the same. The same may be said of the Sharp's military, and in fact might be said of any arm using the same ammunition—that of the long-range Springfield. It was observed that little or no difference in elevation was required with cartridges containing 70 and 80 grains of powder, the weight of bullet, 500 grains, remaining the same.

The Martini-Henry was next fired at this range, but the target was not reached.

The service rifle was also fired a few times with 70 grains of powder and a lubricated grooved bullet weighing 500 grains. Not being able to locate the bullets no record was made of the elevation. Later, however, these bullets were found beyond the target. It was observed not only at these, but all other trials at ranges varying from 1,500 to 3,500 yards, that in every case the bullets struck point-on. This was clearly shown not only by the penetration in wood, but in the sand. At the longest ranges the holes in the latter looked as though they had been made with a cane, and the angle of fall was about 65°. This was determined by measuring the height where the target was struck and the horizontal distance below to the point finally hit on the sand. Sand was driven in the points of the bullets, showing clearly how they had struck.

In many instances, at the 3,500 range, the times of flight and angles of elevation could not be determined owing to the fact that the bullets did not hit the target nor strike near enough to it to enable their fall to be heard.

Table of results at 3,500 yards range.

Rifles.	Weights of powder.	Weights of bullets.	Angles of elevation.	Times of flight.	Penetration in white pine.
					Inches.
Long-range Springfield (18-inch twist).	70 grains.	500 grains*	27° 12′ 36″	21. 2 seconds.	10 in sand.
	80 grains.	500 grains.	27° 12′ 36″	20. 8 seconds.	2+6 in sand.
Long-range Springfield (19⅝-inch twist).	70 grains.	500 grains.	29° 45′ 36″	....	10 in sand.
	80 grains.	500 grains.	29° 45′ 36″	....	10 in sand.
Sharp's (Borchardt)	70 grains.	500 grains.	No record.	No record.	10 in sand.
	80 grains.	500 grains.	No record.	No record.	10 in sand.
Martini-Henry	85 grains.	480 grains.		(‡)	
Springfield (service)	70 grains.	405 grains†		(‡)	
	70 grains.	500 grains†	No record.	No record.	10 in sand.

*Patched. †Grooved and lubricated. ‡Failed to reach target.

3,000 YARDS RANGE.

At 3,000 yards the angle of fall with the long-range 18-inch twist gun was about 35° as nearly as could be judged from the bullet holes in the target and in the sand. For some reason, not understood, the quicker twist gun seemed to require a little less elevation than the others at the same range. The penetration with all guns was less in the sand than at 3,500 yards. This was due to less vertical height fallen through and to the flatter trajectory, which caused the bullets to move to the front after striking and make a cut in the sand.

At the 3,000-yard range the target was hit several times by the 18-inch twist Springfield and the Sharp's, the 19⅝-inch twist not being fired, as it differed so little from the Sharp's and the supply of ammunition was small. In each case the target was hit where it was one inch in thickness. The bullets passed through and entered the sand about 3 inches. No difference in elevation was used with 70 and 80 grains powder charges, and the penetration appeared precisely the same. A slight difference in times of flight—about one-half second—was observed, the 80 grains, of course, giving the lesser. The angle of elevation with the 18-inch twist was slightly less than with the Sharp's, which probably accounts for its time being also one second less than with the Sharp's. Having but about 50 Martini rifle cartridges to use at the two ranges of 2,500 and 3,000 yards, the target at the latter was not hit, but the bullets fell in such close proximity to it as to enable the angle of elevation and time of flight to be obtained. The same was true of the service rifle with the 500 grains grooved bullet. It will be seen by the table summarizing these results that greater penetration was obtained with the service, with 15 grains less powder but 20 grains more lead, than with the Martini, and that the time of flight was the same. The initial velocity was in favor of the Martini, but it was neutralized by the less weight of lead. Attempts to reach the 3,000 yards target with the service rifle and cartridge were unsuccessful, the utmost range being 2,950 yards. The weather was very unfavorable for so light a bullet, head and cross winds acting on it with much greater effect than on the heavier long-range bullets. The difference in weight is strikingly illustrated by that of proportionate weights of shot for the 11-inch rifle of 500 and 617.5 pounds.

As the bullets did not fall within less than 50 yards of the target the time could not be determined, and the angle, which was constantly varied with the hope of ultimately gaining the last 50 yards, was to some extent a matter of doubt. It was apparent that the maximum range was obtained with an angle not exceeding 32°, and possibly less.* This was manifest when using the long-range gun at 3,500 yards; for with an angle of slightly less than 25° the bullets were falling all around the target, and on increasing the elevation to 32°, the maximum allowed by the sight, they instantly fell off from 100 to 150 yards. The greatest range obtained with the long-range 18-inch twist gun was 3,680 yards. The angle under which it was obtained is also a matter of doubt, owing to the constant changes to produce the greatest range, and the fact that bullets thrown under one angle may not be found in the sand at the time, but may be discovered later, when it is impossible to say at what time they were fired. The angle in any event did not exceed 32°.

*The maximum range of the Martini having been attained with an angle of 26° 51′, and a mean of the observed angles of the long-range Springfield at 3,500 yards being very nearly the same, 27° may, it is thought, be accepted without material error as corresponding to the maximum range. For reasons previously stated, however, of the absolute correctness of the angles obtained I am not entirely certain.

Table of results at 3,000 yards range.

Rifles.	Weights of powder.	Weights of bullets.	Angles of elevation.	Times of flight.	Penetration in white pine.
					Inches.
Long-range Springfield (18-inch twist).	70 grains.	500 grains*	17° 48′ 11″	15.5 seconds.	1+6 to 8 in sand.
	80 grains.	500 grains.	17° 48′ 11″	15.25 seconds.	1+6 to 8 in sand.
Sharp's (Borchardt)	70 grains.	500 grains.	19° 47′ 15″	16.5 seconds.	6 to 8 in sand.
	80 grains.	500 grains.	19° 14′ 33″	16.25 seconds.	1+6 in sand.
Martini-Henry	85 grains.	480 grains.	22° 21′ 34″	17.67 seconds.	5 in sand.
Springfield (service).....	70 grains.	405 grains†	Utmost range	2,950 yards.	4 to 5 in sand.
	70 grains.	500 grains†	20° 37′ 28″	17.77 seconds.	6 to 8 in sand.

* Patched. † Grooved and lubricated.

2,500 YARDS RANGE.

At this distance the long-range Springfield 19⅝-inch twist and the Sharp's were fired with both 70 and 80 grain charges, the service Springfield rifle and carbine with the service-rifle cartridge, and the Martini-Henry rifle and carbine with their respective cartridges.

At this range the targets were too nearly horizontal for the guns firing heavy bullets, and the penetrations were to some extent lengthwise with the target rather than through it. The Martini rifle balls plowed their way up almost 2 inches without getting through the two boards, but with a vertical target during former trials passed entirely through two boards and part way into a third. The long-range Springfield bullets passed through two boards easily, giving a penetration of about 3 inches, and then entered the sand to a depth of about 4 inches. When striking a single-board target the penetration in sand was but little more than before.

The penetrations, times of flight, &c., of these guns, together with those of the service, and the Martini and service carbines, are given below:

Table of results at 2,500 yards range.

Rifles and carbines.	Weights of powder.	Weights of bullets.	Angles of elevation.	Times of flight.	Penetration in white pine.
					Inches.
Long-range Springfield (19⅝-inch twist).	70 grains.	500 grains*	12° 43′ 36″	11.32 seconds.	3 + sand.
	80 grains.	500 grains.	12° 49′ 17″	11 4 seconds.	3 + sand.
Sharp's (Borchardt)	70 grains.	500 grains.	11° 39′ 29″	11. seconds.	3 to 4 in sand.
	80 grains.	500 grains.	12° 3′ 0″	11.25 seconds.	3 to 4 in sand.
Martini-Henry	85 grains.	480 grains*	17° 5′ 12″	14.5 seconds.	2.
Springfield (service)........	70 grains.	405 grains†	17° 8′ 16″	17.75 seconds.	1.37.
Springfield carbine (service).	70 grains.	405 grains†	18° 47′ 7″	....	1 + sand.
Martini-Henry carbine	70 grains.	410 grains*	17° 19′ 31″	15.25 seconds.	1.75.

* Patched. † Grooved and lubricated.

2,000 YARDS RANGE.

At this range the service rifle, service carbine with both rifle and carbine cartridges, the 18-inch twist carbine, and the Martini-Henry were fired. The penetrations were very uniform for all these guns and are given in the table as 1½ inch. Though passing through but one board in most cases into the sand, the penetrations were really much greater owing to the parallelism of target and trajectories. The most striking point developed was that the penetrations of the carbine with carbine and rifle cartridges were not only equal to each other, but to that of the

rifle as well. That of the Martini was the same. The targets should have been perpendicular at so short a range to have shown any material difference, which, for reasons later explained, probably did not exist. The times and angles were taken, the latter being with the 18-inch twist a little less than with the service carbine.

Table of results at 2,000 *yards range.*

Rifles and carbines.	Weights of powder.	Weights of bullets.	Angles of elevation.	Times of flight.	Penetration in white pine.
					Inches.
Springfield rifle	70 grains.	405 grains.	10° 6′ 8″	9.25 seconds.	1.5 + sand.
Springfield carbine (service).	55 grains.	405 grains.	10° 12′ 43″	10.37 seconds.	1.5 + sand.
	70 grains.	405 grains.	9° 21′ 8″	9.62 seconds.	1.5 + sand.
Springfield carbine (18-inch twist).	70 grains.	405 grains.	9° 1′ 47″	9.56 seconds.	1.75.
Martini-Henry	70 grains.	410 grains*	10° 16′ 1″	9.37 seconds.	1.5 + sand.

*Patched.

1,500 YARDS RANGE.

The service carbine with both rifle and carbine cartridges and the 18-inch twist experimental carbine with rifle cartridges were fired at this range, the Martini having been fired during the former trial at the vertical target. The penetrations are not, therefore, strictly comparable, because the inconvenience of a horizontal target at so short a range was greatly magnified over that at 2,000 yards. When using the rifle cartridge the bullets passed through the thickest portion of the target (two boards), but at such an angle as to give at least 3 inches penetration. The angle of elevation was slightly in favor of the quicker-twist carbine. When using the carbine cartridges the target was hit several times, but invariably in a part which was but one board thick. The bullet traversed about 1½ inch in getting through and then entered the sand. All penetrations in sand were very much reduced as the range decreased, a cut being made a few inches in length. Except at 1,500 yards range the bullets generally remained in the sand; but at this range they very frequently left it and passed a long way beyond. As tending to show how little sand is required to stop a bullet at short range the service rifle was fired into sand from 5 to 10 feet away. The bullets did not enter more than 3 or 4 inches, their whole power being expended in deforming themselves—in reality turning themselves inside out. The high velocity at which they were moving gave the particles of sand no time to admit of displacement before the bullets were destroyed. A few are submitted showing this singular effect. At long ranges, where the velocity was comparatively low, bullets penetrated to a depth of 10 to 12 inches without injury to their shape.

Table of results at 1,500 *yards range.*

Carbines.	Weights of powder.	Weights of bullets.	Angles of elevation.	Times of flight.	Penetration in white pine.
					Inches.
Springfield carbine (service).	70 grains.	405 grains.	6° 38′ 5″	5.5 seconds.	3.
	55 grains.	405 grains.	6° 38′ 5″	5.75 seconds.	1.5 + sand.
Springfield carbine (18-inch twist).	70 grains.	405 grains.	6° 28′ 25″	5.5 seconds.	3.

ASSIMILATION OF VELOCITIES AT LONG RANGES OF BULLETS OF EQUAL WEIGHT HAVING DIFFERENT INITIAL VELOCITIES.

The explanation of the fact that the Springfield rifle, though giving greater initial velocity, has practically no greater range than the carbine using the rifle cartridge, and that the long-range guns require no more elevation at great ranges with a 70-grain charge of powder than with 80 grains, the weight of bullets being the same, is that the slight difference in initial velocity is neutralized by the resistance of the air long before the ultimate range is reached, and the velocity which the bullet has on reaching the earth, or final velocity, is due largely to gravity. For points beyond that at which this approximation of velocities takes place the same elevation is of course required. All, then, depends on the weight of lead thrown. At 1,000 yards a difference in elevation corresponding to but 20 yards in range was observed between the 70 and 80 grain charges.

In addition to the cases referred to this was shown at 2,000 yards, the service-carbine giving the same penetration with carbine and rifle cartridges—though differing in powder charge by 15 grains—and with but slightly different elevations and times of flight. The assimilation of velocities of the same bullet thrown under different initial velocities is also shown by the table of computed velocities in my report of May 9.

EFFECT OF WEIGHT IN CONSERVING VELOCITY.

The great advantage of weight in conserving velocity was evident not only when firing against heavy winds, but in calm weather at the greater ranges. More power is, of course, required to communicate an equal velocity to a heavy bullet than to a light one, but the ability to overcome resistance of air enables us to accept as a standard a much less initial velocity, and consequently not unduly increase the recoil. More depends within ordinary limits on the weight of bullet than of powder. This was clearly manifest in these experiments when the ultimate range of the Martini—though using 15 grains more powder—was found to be between that of the service and long-range guns, its weight of lead thrown being between theirs.

The times of flight are in the same order. The resistance to lateral deviation by cross-winds was decidedly favorable to the heavy bullets at all the higher ranges.

POWDER CHARGE.

Variations in the powder charge within ordinary limits having been shown to have little or no influence at the longer ranges, the advantages of a charge as heavy as that of the Martini must be sought for when the arm is used at closer quarters. The higher the initial velocity the flatter the trajectory until a range is attained at which different velocities become sensibly equal. High velocities, however, cannot be obtained without an accompanying recoil.

At 1,000 yards, as already stated, the difference in elevation required by the use of 70 and 80 grain charges in the long-range Springfield was very slight. With the service gun the high initial velocity has been a prominent feature, and the same is true of those of most of the continental countries. In passing from the service to the long-range gun, however, the Martini, formerly throwing the heaviest bullet, is placed between them. At short ranges great power is not required, all of the guns having a surplus. If battles are to be lost and won at extreme

ranges, a flat trajectory is of no great consequence, and the rifle should be used to give a curved fire like that of mortars. If fought within short ranges—1,000 yards—as most of our Indian fighting is done, then the weight of the powder charge should be to the bullet as at present, 70 to 405, or in the case of the Martini, 85 to 480.

NATURE OF BULLET.

During these trials patched and lubricated grooved bullets of the same weight were used. No trials for accuracy in the sense ordinarily understood have yet been made. It is sufficient to say, however, that the experience of this country with the service bullet affords the strongest probability that the heavy grooved bullet will prove as satisfactory as the lighter one, especially with a little greater twist on account of the increased length of bullet.

The advantages of this form of bullet for the service cannot be magnified. Cartridges made as at present are absolutely water-proof; the bullet is securely held and cannot be displaced when the cartridge is carried in the belt as is now the custom. With the patched bullet the reverse obtains. The roughing up of the patch is ruinous to accuracy, and the ease with which the bullet may be pulled from the shell renders the use of cartridges so constructed highly objectionable.

POWER OF THE SPRINGFIELD RIFLE AND CARBINE.

The record of the service rifle with service cartridge at 2,500 yards is a complete refutation of the assaults that have been made on this arm from time to time. The penetration was from $1\frac{3}{8}$ to $1\frac{1}{2}$ inch, about $\frac{1}{4}$ to $\frac{3}{8}$ of an inch greater than at the first trial with vertical target. This is amply sufficient to disable if not to kill. The angle of fall was such as to cause the bullets to strike the horizontal target nearly at right angles. At a range of 2,950 yards the target was not hit, but the penetration in sand was greater than at 2,500 yards. That the extreme range of this gun with service cartridge was equal to that of one using nearly one-fifth more powder and one-fourth more lead was not claimed; but that it was effective at a range beyond which it is impossible to shoot any gun from the shoulder, was maintained and is clearly proved by these experiments. But by far the most remarkable fact developed was that the much-abused carbine should, when firing the service-rifle cartridge, give, at 2,500 yards, a penetration of 1 inch in pine and 2 to 3 inches more in sand. The penetration in pine would no doubt have been equal to that of the rifle had a thicker portion of the target been struck. The Martini carbine gave the same penetration except in one instance, when it was $1\frac{3}{4}$ inch. The greater penetration of the Martini bullet was due to two causes: First, its 5 grains more lead, and these trials showed that at long ranges each grain of lead was worth its weight in gold for producing a certain effect; and second, the dragging effect of the cannelures on the service bullet in passing through wood. This last is especially true when the bullet is moving with a low velocity, as the fibers of the wood have time to spring back while the bullet is forcing its way through. This was manifest on examination of the bullets, the lead at the shoulders of the grooves being dragged irregularly to the rear. A few are submitted showing this peculiarity. As stated in a former report, this is ordinarily of no consequence, since bullets are not shot through wood but air, at animate objects. In trying to reach the 2,500 yards target with the carbine the bullets were thrown at least 200 yards beyond.

At ranges up to 1,000 yards the Springfield rifle is one of the most accurate known, due in great measure to the care exercised in its manufacture, and to the excellence and uniformity of its cartridges produced at the Frankford Arsenal.

At higher ranges, except in calm weather, it could hardly be expected to compete with guns using heavy charges, especially of lead.

CONCLUSIONS.

As a result of these trials it will be seen that the service rifle with the service cartridge is amply sufficient to disable and possibly to kill up to nearly 3,000 yards; that the same is true of the carbine using the rifle cartridge; that the 500-grain bullet fired from any rifle with a twist sufficient to give the necessary rotation will range nearly 3,700 yards; that variations in weight of powder charge within ordinary limits have no effect on elevation at extreme ranges, velocities approximating to each other; and finally, that with a cartridge prepared as at present, but with an increased weight of ball, the service rifle may be made, if desired, as long a ranging arm as any known.

As regards accuracy, further experiments will be necessary to determine the conditions of twist, &c., required.

Appended will be found a table giving a summary of all the results obtained at Sandy Hook, N. J., and this post up to the present time.

Further experiment will be made with the service gun and heavy bullets.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A.

To the COMMANDING OFFICER, *National Armory.*

Summary of results of long-range firing at Springfield, Mass., and Sandy Hook, N. J. (both trials), by Captain John E. Greer, Ordnance Department, U. S. A.

Rifles.	Weights of powder.	Weights of balls.	Initial velocities.	Recoil.	Ranges.	Angles of elevation.*	Times of flight.	Penetration in white pine.
	Grs.	*Grs.*	*Feet.*	*Foot-lbs.*	*Yards.*		*Sec.*	*Inches.*
Springfield (service)..	70	405†	1, 326. 9	9. 33	1, 500	5° 58′ 23″	....	
					2, 000	11° 2′ 4″	9. 25	1. 5.
					2, 500	17° 8′ 16″	17. 75	1. 37.
					2, 800	24° 8′ 42″	....	
					2, 950	27° 12′ 36″	....	4 to 5 in sand.
		500†	1, 266	11. 75	1, 500	5° 33′ 51″	....	
					3, 000	20° 37′ 28″	17. 77	6 to 8 in sand.
					3, 500	No record.	....	10 in sand.
Springfield, long-range ($19\frac{5}{8}$-inch twist).	70	500	1, 220. 8	10. 83	1, 500	4° 52′ 17″	....	
					2, 500	11° 43′ 49″	11. 32	3+sand.
					3, 500	29° 45′ 36″	....	10 in sand.
	80	500	1, 268. 5	12. 67	1, 500	4° 38′ 37″	....	
					2, 000	8° 16′ 2″	....	3+sand.
					2, 500	11° 43′ 49″	11. 4	5. 25.
					3, 200	20° 51′ 37″	....	2+sand.
					3, 500	29° 45′ 36″	....	10 in sand.

* Mean of all at both trials; in many instances anomalous.

† Grooved and lubricated.

Summary of results of long-range firing at Springfield, Mass. &c.—Continued.

Rifles.	Weights of powder.	Weights of balls.	Initial velocities.	Recoil.	Ranges.	Angles of elevation.*	Times of flight.	Penetration in white pine.
	Grs.	*Grs.*	*Feet.*	*Foot-lbs.*	*Yards.*		*Sec.*	*Inches.*
Springfield, long-range (18-inch twist).	70	500	1,226.9	11	3,000	17° 48′ 11″	15.5	1+6 to 8 in sand.
					3,500	27° 12′ 36″	21.2	10 in sand.
	80	500	1,280.9	12.87	3,000	17° 48′ 11″	15.25	1+6 to 8 in sand.
					3,500	27° 12′ 36″	20.8	2+6 in sand.
	70	500	1,205.8	11.3	2,500	11° 39′ 29″	11.	3 to 4 in sand.
					3,000	19° 47′ 15″	16.5	6 to 8 in sand.
					3,500	No record.	....	10 in sand.
Sharp's (Borchardt).	80	500	1,266.4	13.63	2,500	12° 3′ 0″	11.25	3 to 4 in sand.
					3,000	19° 14′ 33″	16.25	1+6 in sand.
					3,500	No record.	....	10 in sand.
Martini-Henry.....	85	480	1,263.4	12.5	2,000	9° 48′ 57″	....	3+sand.
					2,500	15° 12′ 30″	14.5	2.5
					3,000	22° 21′ 34″	17.67	5 in sand.
					3,200	26° 51′ 0″	...	6 in sand.
					3,500	Failed to reach target.		
CARBINES.								
Springfield	55	405†	1,112.9	7	1,500	6° 38′ 5″	5.75	1.5+sand.
					2,000	10° 12′ 43″	10.37	1.5.
	70	405†	1,262.5	9.6	1,500	6° 38′ 5″	5.5	3.
					2,000	9° 21′ 8″	9.62	1.5+sand.
					2,500	18° 47′ 7″	23.3	1+sand.
Springfield (18-inch twist).	70	405†	1,250.5	9.6	1,500	6° 28′ 25″	5.5	3.
					2,000	9° 1′ 47″	9.56	1.75.
Martini-Henry......	70	410	1,126.5	9.6	1,500	..	..	3+sand.
					2,000	10° 16′ 1″	9.37	1.5+sand.
					2,500	17° 19′ 31″	15.25	1.75.

* Mean of all at both trials; in many instances anomalous. † Grooved and lubricated.

NATIONAL ARMORY,
Springfield, Mass., June 26, 1880.

The CHIEF OF ORDNANCE, U. S. A.,
Washington, D. C.:

SIR: I have the honor to forward herewith, for the information of the department, the final report of the experiments made by Captain Greer, under my instructions, with a view to improve the range and accuracy of fire of the service small arms.

Very respectfully, your obedient servant,

J. G. BENTON,
Colonel of Ordnance, Commanding.

NATIONAL ARMORY,
Springfield, Mass., June 22, 1880.

SIR: In my report of November 15, 1879, on long-range firing, it was stated that trials would be made for the purpose of ascertaining the accuracy of heavy bullets, grooved and lubricated, fired from rifles with various twists and number of grooves, as compared with the service and patched bullets fired from the Springfield service and long-range rifles respectively.

Bullets differing in weight, hardness, caliber, and form have been experimented with for the following reasons: With respect to weight, because it was found that a largely increased range could be obtained without changing other conditions simply by increasing the weight of the service bullet about one fourth, and, as was previously well known, with less liability of the bullets being deflected by winds.

Variations in hardness were made for the purpose of diminishing, if not eradicating, "leading" of the grooves. This is to some extent incidental to the use of unpatched bullets; but, unless abnormal, has been shown by our long experience to have little or no effect on accuracy. This is clearly manifest from the comparative records in this report of the naked and patched bullets, although it might have been reasonably expected that there would be more decided leading with the long, heavy bullets than with the shorter and lighter ones in our service.

Variations in diameter of the bullet were made because when using softer bullets the "upsetting" due to the shock was sufficient to fill the grooves and insure rotation. Finally, bullets with flat bases and points were tested with the view both of shortening the total length of the cartridge and, if the accuracy were found equally good, to give a safer cartridge for magazine guns.

Variations were also made in the powder charge, 70, [illegible], 80, and 90 grains being tried. Seventy grains was largely adhered to, being the capacity of the present service shell, and it was not thought desirable, unless absolutely necessary, to rechamber the thousands of guns in service for a cartridge which the average soldier is utterly unable to fire because of the recoil, and still more because as good results were obtained with this charge and heavy bullet as with carefully prepared cartridges containing 80 grains and patched bullet. Moreover, if range alone be desired, the addition of a few grains of powder has very little appreciable effect. In favor of the heavier charge is the higher initial velocity with corresponding flatness of trajectory and increased dangerous space at ordinary ranges. Opposed to it, in addition to the reasons mentioned above, is the increased weight and inconvenience of carrying the longer cartridge. Various brands of powder were [illegible] in these trials with the view of finding the best combination possible.

Rifles were tested with twists and grooves as follows:

Rifles.	Twist.	No. of grooves.
Springfield service, caliber .45	22 inches.	3
Springfield special, caliber .45	18 inches.	3
Springfield special, caliber .4525	18 inches.	6
Springfield long range, caliber .4525	1[illegible] $\frac{5}{8}$ inches.	6
Springfield service, with lengthened chamber, caliber .45	22 inches.	3
Springfield special, with lengthened chamber, caliber .4525	18 inches.	6

The first three have been fired mainly with 70 grains powder and 500-grain bullet, the latter with 80 grains powder and same bullet, or patched bullet of equal weight. The lubricant employed in all cartridges prepared at this post was sperm oil and beeswax, while that in cartridges manufactured at Frankford Arsenal was "Japan wax." The former has been found to give the best results for accuracy, though it is uncertain whether its use would be advisable for cartridges likely to go in store, owing to the liability of acid to be present in the oil.

Considering the number of variables entering the problem to be

solved—that is, to get the best accuracy with increased range and moderate recoil and still have a practical form of cartridge for service—the number of targets is comparatively limited.

Enough, however, has been obtained to show that rifles with either 3 or 6 grooves, with a twist as rapid as 18 inches, have no superiority over the service with the twist of 22 inches.

The twist of the service rifle was found ample even for a bullet of a length nearly one-third greater than the service.

In support of this statement is the excellent record made with the service gun chambered for a shell 2.4 inches long, loaded both with 80 and 90 grain charges and 550-grain bullet, the latter being 1.45 inch long or nearly 3¼ calibers. The accuracy was very satisfactory, but the recoil of a 9-pound gun when firing such a cartridge was so severe as to preclude its use in service.

It should be borne in mind in refeience to the latter statement that the initial velocity of the 550-grain bullet with 90 grains powder crimped in the shell in the usual manner is greatly less—about 45 feet—than that of the patched bullet of the same weight when fired with 120 grains of powder. This is due to the more perfect development of gas in the former case, the resistance to the bullet leaving shell and bore being much greater. The velocity of the 500-grain patched bullet fired with 80 grains of powder, in the long-range Springfield, is exactly that—1,270 feet—of the grooved and lubricated bullet of the same weight fired with 70 grains of powder in the service rifle.

The cartridges prepared at this armory gave better results for accuracy than those received from Frankford Arsenal. This may be due to any one of several causes, possibly to all. The bullet as made there was not an exact duplicate of the model; the powder was of materially higher velocity than that used here, though in one case obtained at the same works—the Hazard Powder Company's. The lubricant differed, as before stated, as did also the crimping of the shell.

Summaries of the results of firing at 1,000, 800, 500, and 300 yards are appended, together with the record of each day's firing. From the former it will seen that the service rifle with 70 grains Hazard F. G. powder and 500-grain bullet, $\frac{1}{16}$ tin, grooved and lubricated essentially like the service, gives an absolute deviation of 24.9 inches at 1,000, 14.9 inches at 800, 9.6 inches at 500, and 3.7 inches at 300 yards. *

The same rifle chambered for an 80-grain powder charge, other conditions being the same as before, gives a deviation of 21.5 inches at 1,000, 16.3 inches at 800, 8.1 inches at 500, and 4.6 inches at 300 yards.

Comparing these results with the known performance of the service rifle with the best service cartridge that has been produced, which is 28.4 inches at 1,000, 18.1 inches at 800, 8.7 inches at 500, and 4.5 inches at 300 yards, these being the average from a number of rifles, it will be seen that there is little or no advantage in the heavier bullet at ranges under 800 yards. At 1,000 yards the superiority of the heavy bullet is apparent with both 70 and 80 grains powder, being most so with the latter. It only remains to compare the previous records with that of the "long range Springfield rifle," with its special ammunition, a cartridge which is utterly unfit for any purpose other than that of the target ground.

The absolute deviation—cartridges being most carefully prepared—was found to be 24.1 inches at 1,000 and 8.3 inches at 500 yards. This is about the same as the service rifle with 70 grains powder and 500

*This record was largely made during the winter and spring, when the weather was very unfavorable on account of cold and heavy winds.

grains bullet at 1,000 yards, and the service with the service cartridge at 500 yards.

From the above it will be seen that but little is gained in point of accuracy over the present service combination of rifle and cartridge at ranges at which accuracy in the sense of target or sharpshooting is of much importance, that is, at ranges at which individual objects may be struck. There is, it is true, a slight gain beyond 500 yards with the heavy bullet, but its chief advantage when fired with 70 grains of powder is to be found in the fact that a greatly increased range may be attained which may be utilized in firing at troops in masses. With 80 grains of powder we recover the velocity previously lost by the use of this bullet, and consequently flatten the trajectory at short ranges to correspond with the service. We have, therefore, a choice of three combinations—first, that already existing; second, the rifle remaining absolutely the same, one in which the cartridge alone is changed by replacing the 405-grain bullet by one of 500 grains; and, third, rechambering all rifles in service for a shell 2.4 inches long, using 80 grains of powder and the bullet last mentioned.

The advantages of the first system are too well known to require enumerating. Those of the second are to be found in the fact that we can, without expense, attain results up to several hundred yards at least equal to and at points beyond slightly better than with the service combination, while we can increase its maximum range about 700 yards. This is accomplished at the cost of a somewhat greater recoil, together with increased load to the soldier, 100 cartridges weighing about 1 lb. and 6 oz. more than the same number of the service. Finally, with the 80-grain charge and heavy bullet we can slightly better the results of the second combination, but this is accomplished at the cost of still greater recoil and increased weight to be carried, 100 cartridges weighing 2 lbs. 1 oz. more than the same number of the service. In addition is the expense of rechambering the hundred or more thousands of rifles already manufactured. Still, if the Army is desirous of this system, the expense to the Ordnance Department should not be considered.

One important application of this cartridge, if adapted for service, would be for machine guns. These should possess the power of throwing shots at the greatest practicable ranges at troops in masses. The opportunity for their use may never arrive in this country, but the remotest contingency should be provided for.

It only remains to add that of all cartridges tried that prepared at this post with 80 grains of Hazard F. G. powder of a velocity from 1,310 to 1,330 feet, and a 500-grain bullet $\frac{1}{16}$ tin, with lubricant of sperm oil and beeswax, has proved the most satisfactory. The 70-grain cartridge prepared in a similar manner has also given excellent results. No leading of moment has been found with either of these cartridges, and, what is still more satisfactory, no other rifle is required for their use than the service, with, for the 80-grain charge, a lengthened chamber.

Very respectfully, your obedient servant,

JOHN E. GREER,
Captain of Ordnance, U. S. A.

To the COMMANDING OFFICER, *National Armory.*

Summary of results of firing at 1,000 yards.

Rifle.	Powder.		Bullet.			No. of targets.	Mean deviations.	Remarks.
	Weight.	Kind.	Weight.	Caliber.	Kind.			
	Grs.		*Grs.*				*In.*	
Service, 22-inch twist, 3 grooves.	70	Service	405	.458	Service	14	27.6	Bullet 1-16 tin.
	70	Hazard, F. G	480	.446	Long-range Springfield, grooved and lubricated.	6	23.8	Bullet 1-19 tin.
	70	do	490	.458	Like service	12	24.1	Bullet 1-12 tin.
	70	do	500	.458	Like service, except flat base	12	24.7	Bullet 1-12 tin.
	70	do	500	.456	Flat base; flat point	2	26.2	Bullet 1-12 tin.
	70	do	500	.456	Flat point No. 2	2	24.6	Bullet 1-18 tin.
	70	do	500	.452	Flat point No. 1	1	2[illegible].4	Bullet 1-18 tin.
	65	do	500	.4555	Like service	4	32.8	Bullet 1-12 tin.
	70	do	500	.4555	Like service	19	27.4	Bullet 1-12 tin.
	70	do	500	.4555	Like service	43	24.9	Bullet 1-16 tin.
	70	do	5 0	.458	Like service; machine made	19	29.1	Bullet 1-12 tin.
	70	do	500	.458	Like service; machine made	18	30.5	Bullet 1-17 tin.
	70	Oriental	500	.458	Like service; machine made	12	29.6	Bullet 1-12 tin.
	70	do	500	.458	Like service; machine made	12	26.9	Bullet 1-17 tin.
18-inch twist, 3 grooves.	70	Hazard, F.G.	480	.446	Long-range Springfield, grooved and lubricated.	5	22	Bullet 1-19 tin.
	70	do	490	.458	Like service	4	25	Bullet 1-12 tin.
	70	do	500	.458	Like service, except flat base	2	33.4	Bullet 1-12 tin.
	70	do	500	.456	Flat base; flat point	2	24.3	Bullet 1-12 tin.
	70	do	500	.456	Flat base No. 2	2	24.5	Bullet 1-18 tin.
	70	do	500	.442	Flat base No. 1	1	20.3	Bullet 1-1[illegible] tin.
	70	do	500	.4555	Like service	2	25	Bullet 1-12 tin.
	70	do	500	.458	Like service; machine made	2	26	Bullet 1-12 tin.
	70	do	50	.458	Like service; machine made.	2	29.4	Bullet 1-17 tin.
	70	Dupont	500	.458	Like service; machine made	2	30.3	Bullet 1-12 tin.
18-inch twist, 6 grooves.	70	Hazard, F. G.	480	.446	Long-range Springfield, grooved and lubricated.	2	18.6	Bullet 1-18 tin.
	70	do	49	.458	Like service	4	29.1	Bullet 1-12 tin.
	70	do	500	.458	Like service, except flat base	2	26.9	Bullet 1-12 tin.
	70	do	500	.456	Flat base; flat point	2	26	Bullet 1-12 tin.
	70	do	500	.4 6	Flat point No. 2	2	27.3	Bullet 1-18 tin.
	70	do	500	.4 2	Flat point No. 1	1	28.1	Bullet 1-18 tin.
	70	do	500	.452	Like service	1	17.8	Bullet 1-12 tin.
Service with lengthened chamber,* 22-inch twist, 3 grooves.	70	Service	405	.458	Service	4	24.8	Bullet 1-16 tin.
	80	Hazard, F. G	500	.4555	Like service	21	21.5	Bullet 1-16 tin.
	80	do	500	.4555	Like service	18	24.2	Bullet 1-12 tin.
	80	do	550	.458	Like service	7	24.1	Bullet 1-12 tin.
	90	do	550	.458	Like service	3	24.7	Bullet 1-12 tin.
	80	do	500	.458	Like service; machine made.	16	26.5	Bullet 1-12 tin.
	80	do	500	.458	Like service; machine made	7	32.1	Bullet 1-17 tin.
	80	Oriental	500	.458	Like service; machine made	10	30.5	Bullet 1-12 tin.
	80	do	500	.458	Like service; machine made	9	28.5	Bullet 1-17 tin.
	75	Dupont	5 0	.458	Like service; machine made	5	25.2	Bullet 1-12 tin.
	80	do	500	.458	Like service; machine made.	4	27.1	Bullet 1-12 tin.
Long-range Springfield, 19⅝-inch twist, 6 grooves.	80	Hazard, F. G	500	.446	Patched	16	24.1	Cal. of bullet when patched, 4[illegible]3. Bullet 1-19 tin.

*Chamber of gun lengthened for shell 2.4 inches long.

Summary of results of firing at 800 yards.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of targets.	Mean deviations.	Remarks.
	Grs.		*Grs.*				*In.*	
Service, 22-inch twist, 3 grooves.	80	Hazard F.G.	500	.4555	Like service	3	14.9	Bullet 1-16 tin.
Service, with lengthened chamber * 22-inch twist, 3 grooves.	75	Dupont	500	.458	Like service; machine made	14	16.97	Bullet 1-12 tin.
	80	do	..		Like service; machine made	10	20.46	Bullet 1-12 tin.
	80	Hazard, F.G.	500	.458	Like service; machine made	6	17.45	Bullet 1-12 tin.
	80	do	500	.458	Like service; machine made	4	16.3	Bullet 1-17 tin.
	80	do	500	.4555	Like service	4	18.2	Bullet 1-12 tin.
	80	do	500	.4555	Like service	8	16.3	Bullet 1-16 tin.
18-inch twist, 6 grooves, with lengthened chamber.*	80	Hazard, F.G.	500	.4555	Like service	10	15.5	Bullet 1-16 tin.
Long-range Springfield, 19⅝-inch twist, 6 grooves.	80	Hazard, F.H.	500	.446	Patched	5	16.4	Cal. of bullet when patched, .453. Bullet 1-19 tin.

* Chamber of gun lengthened for shell 2.4 inches long.

Summary of results of firing at 500 *yards.*

Rifle.	Powder.		Bullet.			No. of targets.	Mean deviations.	Remarks.
	Weight.	Kind.	Weight.	Caliber.	Kind.			
	Grs.		*Grs.*				*In.*	
Service, 22-inch twist, 3 grooves.	70	Service	405	.458	Service	12	9.4	Bullet 1-16 tin.
	70	Hazard, F.G.	480	.446	Long-range Springfield, groove and lubricated.	4	10.1	Bullet 1-19 tin.
	70	....do	490	.458	Like service	2	7	Bullet 1-12 tin.
	70	....do	500	.458	Used at Sandy Hook; full at point.	1	16.9	Bullet 1-12 tin.
	70	....do	500	.458	Shoulder at front of shell	1	12.9	Bullet 1-12 tin.
	70	....do	500	.458	Like service, except at base.	4	9	Bullet 1-12 tin.
	70	....do	500	.45	Flat base; flat point	1	13.5	Bullet 1-12 tin.
	70	....do	500	.4555	Like service	23	10.5	Bullet 1-12 tin.
	70	....do	500	.4555	Like service	39	9.6	Bullet 1-16 tin.
	65	....do	500	.4555	Like service	2	10.2	Bullet 1-12 tin.
	67	....do	500	.4555	Like service	1	8.7	Bullet 1-16 tin.
	70	....do	500	.458	Like service; machine made	6	10.2	Bullet 1-12 tin.
	70	....do	500	.458	Like service; machine made.	8	9.5	Bullet 1-17 tin.
	70	Dupont	500	.458	Like service; machine made	4	12.8	Bullet 1-12 tin.
	70	Oriental	500	.458	Like service; machine made.	6	9.1	Bullet 1-12 tin.
	70	do	500	.458	Like service; machine made	4	11.6	Bullet 1-17 tin.
18-inch twist, 3 grooves.	70	Hazard, F.G.	480	.446	Long-range Springfield, grooved and lubricated.	3	8.2	Bullet 1-19 tin.
	70	....do	490	.458	Like service.	2	10.5	Bullet 1-12 tin.
	70	....do	500	.458	Used at Sandy Hook; full at point.	1	12.9	Bullet 1-12 tin.
	70	....do	500	.458	Shoulder at front of shell	1	10.5	Bullet 1-12 tin.
	70	....do	500	.45	Flat base; flat point	1	10.3	Bullet 1-12 tin.
	70	....do	500	.458	Like service, except flat base	4	10.4	Bullet 1-12 tin.
	70	....do	500	.4555	Like service	2	9.5	Bullet 1-16 tin.
	70	Dupont	500	.458	Like service; machine made.	2	10.3	Bullet 1 12 tin.
18-inch twist, 6 grooves.	70	Hazard, F.G.	480	.446	Long range Springfield, grooved and lubricated.	3	8.6	Bullet 1-19 tin.
	70	....do	490	.458	Like service	2	8.5	Bullet 1-12 tin.
	70	....do	500	.458	Used at Sandy Hook; full at point.	1	10.9	Bullet 1-12 tin.
	70	....do	500	.458	Shoulder at front of shell	1	14.1	Bullet 1-12 tin.
	70	....do	500	45	Flat base; flat point	2	17.6	Bullet 1-12 tin.
	70	....do	500	.458	Like service, except flat base	4	10.3	Bullet 1-12 tin.
18-inch twist, 6 grooves, with lengthened chamber.*	80	Hazard, F.G.	500	.4555	Like service	10	8	Bullet 1-16 tin.
	80	......do	500	.458	Like service; machine made	2	12.1	Bullet 1-12 tin.
Service, with lengthened chamber, 22-inch twist, 3 grooves.	70	Service	405	.458	Service	8	9.7	Bullet 1-16 tin.
	80	Hazard, F.G.	550	.458	Like service	4	7.7	Bullet 1-12 tin.
	80	....do	500	.4555	Like service	32	8.5	Bullet 1-12 tin.
	80	....do	500	.4555	Like service	65	8.1	Bullet 1-16 tin.
	80	Oriental	500	.458	Like service; machine made	9	12.2	Bullet 1-12 tin.
	80	....do	500	.458	Like service; machine made.	5	10.4	Bullet 1-17 tin.
	80	Hazard, F G.	500	.458	Like service; machine made	12	10.1	Bullet 1-12 tin.
	80	....do	500	.458	Like service; machine made	9	11	Bullet 1-17 tin.
	80	Dupont	500	.458	Like service; machine made	12	11	Bullet 1-12 tin.
	75	....do	500	.458	Like service; machine made.	16	10.5	Bullet 1-12 tin.
Long-range Springfield 19⅝-inch twist, 6 grooves.	70	Hazard, F.G.	500	.458	Like service	1	11.3	Bullet 1-12 tin.
	80	....do	500	446	†Patched	13	8.3	Bullet 1-19 tin.
	80	Dupont	500	.446	†Patched	9	9.	Bullet 1-19 tin.
	80	Oriental	500	.446	†Patched	10	8.9	Bullet 1-19 tin.

* Chamber of gun lengthened for shell 2.4 inches long.

† When patched, caliber .453.

Summary of results of firing at 300 yards.

Rifle.	Powder.		Bullet.			No. of targets.	Mean deviations.	Remarks.
	Weight.	Kind.	Weight.	Caliber.	Kind.			
	Grs.		*Grs.*				*In.*	
Service, 22-inch twist, three grooves.	70	Service	405	.458	Service	1	4.1	Bullet 1-16 tin.
	70	Hazard, F.G.	490	.458	Like service	1	3.3	Bullet 1-12 tin.
	70	....do	490	.456	Flat base; flat point........	1	5.8	Bullet 1-12 tin.
	70	....do	500	.456	Flat base; flat point	1	5.2	Bullet 1-16 tin.
	70	....do	500	.45	Flat base; flat point	1	14.2	Bullet 1-12 tin.
	70	.. do	500	.45	Flat base; flat point	1	24	Bullet 1-16 tin.
	70	....do	500	.458	Used at Sandy Hook; full at point.	1	5.8	Bullet 1-12 tin.
						1	5.4	Bullet 1-12 tin.
	70	...do	500	.458	Shoulder at front of shell ..			
	70	... do	500	.4555	Like service	5	3.7	Bullet 1-16 tin.
	70	.. do	500	.458	Like service; machine made	4	4	Bullet 1-12 tin.
	70	... do	500	.458	Like service; machine made	4	5.1	Bullet 1-17 tin.
	70	Oriental	500	.458	Like service; machine made	3	6.1	Bullet 1-12 tin.
	70	do	500	.458	Like service; machine made	4	5.1	Bullet 1-17 tin.
18-inch twist, 3 grooves.	70	Hazard, F.G.	490	.458	Like service	1	2.5	Bullet 1-12 tin.
	70	....do	500	.458	Used at Sandy Hook; full at point.	1	5.1	Bullet 1-12 tin.
	70	....do	500	.458	Shoulder at front of shell ...	1	7.3	Bullet 1-12 tin.
	70	....do	500	.45	Flat base; flat point........	1	5.3	Bullet 1-12 tin.
	70	....do	500	.45	Flat base; flat point	1	6.2	Bullet 1-16 tin.
	70	....do	500	.456	Flat base; flat point........	1	8.6	Bullet 1-16 tin.
18-inch twist, 6 grooves.	70	Hazard, F.G	490	.458	Like service	1	4.5	Bullet 1-12 tin.
	70	....do	500	.458	Used at Sandy Hook; full at point.	1	4.1	Bullet 1-12 tin.
	70	....do	500	.458	Shoulder at front of shell ...	1	8.4	Bullet 1-12 tin.
	70	.. do	500	.45	Flat base; flat point	1	14	Bullet 1-12 tin.
	70	...do	500	.456	Flat base; flat point........	1	4.2	Bullet 1-16 tin.
18-inch twist, 6 grooves, with lengthened chamber.	80	Hazard, F.G	500	.4555	Like service	14	4.9	Bullet 1-16 tin.
	80	....do	500	.458	Like service; machine made	4	4	Bullet 1-12 tin.
	80	Dupont	500	.458	Like service; machine made	2	5.6	Bullet 1-12 tin.
Service, with lengthened chamber,* 22-inch twist, 3 grooves.	80	Hazard, F.G	500	.4555	Like service	4	4.6	Bullet 1-16 tin.
	80	....do	500	.458	Like service: machine made.	7	5.5	Bullet 1-12 tin.
	80	....do	500	.458	Like service; machine made	3	4.7	Bullet 1-17 tin.
	80	Oriental	500	.458	Like service; machine made	3	6.1	Bullet 1-12 tin.
	80	....do	500	.458	Like service; machine made	1	7.6	Bullet 1-17 tin.
	80	Dupont	500	.458	Like service; machine made	9	5.9	Bullet 1-12 tin.
	75	....do	500	.458	Like service; machine made.	3	4.8	Bullet 1-12 tin.
Long-range Springfield, 19⅝-inch twist, 6 grooves.	80	Hazard, F.G	500	.446	Patched	6	4.2	Bullet 1-19 tin. Caliber of bullet when patched .453.

* Chamber of gun lengthened for shell 2.4 inches long.

1,000 *yards range.—January* 3, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Service	405	.458	Service, 1-16 tin	1	17.6	21.96	30.5
Service	70	....do	405	.458	Service, 1-16 tin	2	18.8	25.7	31.8
						Mean.	18.2	25.33	31.1
Service	70	Hazard, F. G..	490	.458	Like service, 1-12 tin...	1	9.7	12.9	16.1
Service	70	....do	490	.458	Like service, 1-12 tin..	2	14.56	16.6	22.1
						Mean.	12.13	14.7	19.1
18-inch twist, 3 grooves.	70	....do	490	.458	Like service, 1-12 tin...	1	15.55	20.1	25.4
18-inch twist, 3 grooves.	70	....do	490	.458	Like service, 1-12 tin...	2	17.2	15.16	22.9
						Mean.	16.37	17.63	24.1
18-inch twist, 6 grooves.	70	....do	490	.458	Like service, 1-12 tin...	1	26.1	23.9	35.4
18-inch twist, 6 grooves.	70	....do	490	.458	Like service, 1-12 tin....	2	25.3	11.56	27.8
						Mean.	25.7	17.73	31.6
Long-range ...	80	....do	500	.446	Patched, 1-19 tin........	1	23.4	8.3	24.8
Long-range ...	80	... do	500	.446	Patched, 1-19 tin........	2	11.8	11.04	16.1
						Mean.	17.6	9.8	20.4

1,000 *yards range.—January* 3, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V	M. A.
	Grs		*Grs.*						
Service	70	Service	405	.458	Service, 1-16 tin	1	17.6	24.96	30.5
Service	70	...do	405	.458	Service, 1-16 tin	2	18.8	25.7	31.8
						Mean.	18.2	25.33	31.1
Service	70	Hazard, F. G.	500	.458	Like service, except flat base, 1-12 tin.	1	10.3	11.3	15.3
Service	70	...do	500	.458	Like service, except flat base, 1-12 tin.	2	25.6	18.16	31.4
						Mean.	17.9	14.73	23.8
18-inch twist, 3 grooves.	70	...do	500	.458	Like service, except flat base, 1-12 tin.	1	20.8	16.5	26.5
18-inch twist, 3 grooves.	70	...do	500	.458	Like service, except flat base, 1-12 tin.	2	38.8	10.92	40.3
						Mean.	19.8	13.71	33.4
18-inch twist, 6 grooves.	70	...do	500	.458	Like service, except flat base, 1-12 tin.	1	20.	19.9	28.2
18-inch twist, 6 grooves.	70	...do	500	.458	Like service, except flat base, 1-12 tin.	2	18.3	18.	25.7
						Mean.	19.1	18.9	26.9
Long-range	80	...do	500	.446	Patched, 1-19 tin	1	23.4	8.3	24.8
Long-range	80	...do	500	.446	Patched, 1-19 tin	2	11.8	11.04	16.1
						Mean.	17.6	9.8	20.4

1,000 *yards range.—January* 5, 1880.

Rifles.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Service	405	.458	Service, 1-16 tin	1	19.25	15.8	24.9
Service	70	....do	405	.458	Service, 1-16 tin	2	18.9	26.04	32.1
						Mean.	19.7	21	28.5
Service	70	Hazard, F. G.	500	.456	Flat base; flat point, 1-12 tin.	1	16.57	22.57	27.9
Service	70	....do	500	.456	Flat base; flat point, 1-12 tin.	2	12.3	21.28	24.6
						Mean.	14.43	21.92	26.2
18-inch twist, 3 grooves.	70	....do	500	.456	Flat base; flat point, 1-12 tin.	1	13.5	23.9	27.9
18-inch twist, 3 grooves.	70	....do	500	.456	Flat base; flat point, 1-12 tin.	2	11.8	17.1	20.8
						Mean.	12.6	20	24.3
18-inch twist, 6 grooves.	70	....do	500	.456	Flat base; flat point, 1-12 tin.	1	14.7	24.8	28.8
18-inch twist, 6 grooves.	70	....do	500	.456	Flat base; flat point, 1-12 tin.	2	11.32	20.2	23.2
						Mean.	13.01	22	26.
Long-range	80	....do	500	.446	Patched, 1-19 tin	1	14.84	11.64	18.8
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	11.9	19.08	22.5
						Mean.	13.37	15.52	20.7
Service	70	Service	405	.458	Service, 1-16 tin	1	18.9	26.04	32.1
Service	70	....do	405	.458	Service, 1-16 tin	2	19.25	15.8	24.9
						Mean.	19.7	21	28.5
Service	70	Hazard, F. G	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	7.4	9.28	11.9
Service	70	....do	480	.446	......do	2	15.16	21.9	26.6
						Mean.	11.28	15.59	19.2
18-inch twist, 3 grooves.	70	....do	480	.446	......do	1	13.1	15.8	20.5
18-inch twist, 3 grooves.	70	....do	480	.446	......do	2	11.3	15.7	19.4
						Mean.	12.2	15.7	20
18-inch twist, 6 grooves.	70	....do	480	.446	......do	1	13.7	11.72	18
18-inch twist, 6 grooves.	70	....do	480	.446	......do	2	13.63	13.5	19.2
						Mean.	13.66	12.61	18.6
Long-range	80	....do	500	.446	Patched, 1-19 tin	1	11.9	19.08	22.5
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	14.84	11.64	18.8
						Mean.	13.37	15.52	20.7

1,000 *yards range.—January* 16, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Service	405	.458	Service, 1-16 tin........	1	12.2	17.6	20.9
Service	70	Service	405	.458	Service, 1-16 tin........	2	10.8	24.1	26.4
Service	70	Service	405	.458	Service, 1-16 tin........	3	6.1	28.1	28.7
						Mean.	9.4	23.3	25.3
Service	70	Hazard, F. G .	490	.458	Like service, 1-12 tin...	1	6.4	18	19.1
Service	70	.. do	490	.458	Like service, 1-12 tin...	2	21.1	19.2	28.5
Service	70	...do	490	.458	Like service, 1-12 tin...	3	17.5	22.1	28.2
						Mean.	15	19.8	25.3
Service........	70	....do	500	.458	Like service, except flat base, 1-12 tin.	1	10.5	12.2	16.1
Service........	70	....do	500	.458	Like service, except flat base, 1-12 tin.	2	8.64	21.4	23.1
Service........	70	....do	500	.458	Like service, except flat base 1-12 tin.	3	7.8	17.2	18.9
Service........	70	....do	500	.458	Like service, except flat base, 1-12 tin.	4	10.3	20.2	22.7
Service	70	....do	500	.458	Like service, except flat base, 1-12 tin.	5	11.8	24.6	27.3
						Mean.	9.80	19.1	21.6
Service with lengthened chamber.	80	....do	550	.458	Like service, 1-12 tin...	1	10.2	19.8	22.3
	80	...do	550	.458	Like service, 1-12 tin...	2	14.7	18.2	23.4
	80	...do	550	.458	Like service, 1-12 tin...	3	11	19.1	22.
						Mean.	12	19	22.6
Long range ...	80	...do	500	.446	Patched, 1-19 tin...	1	13.4	23.5	27
Long range....	80	...do	500	.446	Patched, 1-19 tin.........	2	5.4	26.6	27.2
Long range....	80	...do	500	.446	Patched, 1-19 tin.........	3	12.6	18.1	22.1
						Mean.	10.5	22.7	25.4

1,000 *yards range.—January* 17, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviation.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs		*Grs*						
Service	70	Service	405	.458	Service, 1-16 tin	1	14.26	22.1	26.3
Service	70	do	405	.458	Service 1-16 tin	2	10.76	20.5	23.2
Service	70	.. do	405	.458	Service, 1-16 tin	3	13.6	30.6	33.5
Service	70	.. do	405	.458	Service, 1-16 tin	4	11	27.5	29.6
						Mean	12.40	25.2	28.1
Service	70	Hazard, F. G..	490	.458	Like service, 1-12 tin ...	1	19.1	19.7	27.4
Service	70	do	490	.458	Like service, 1-12 tin ..	2	21.1	14.5	25.6
Service	70	do	490	.458	Like service, 1-12 tin .	3	12.9	21.4	25
Service	70	.. do	490	.458	Like service, 1-12 tin ...	4	11.8	21.6	24.6
						Mean.	16.2	19.3	25.6
Service	70	do	500	.458	Like service, except flat base, 1-12 tin.	1	13.1	17.5	21.9
Service	70	.. do	500	.458	Like service except flat base, 1-12 tin.	2	19.7	27.5	38.8
Service	70	....do	500	.458	Like service, except flat base, 1-12 tin.	3	10.8	17.5	20.5
Service	70	....do	500	.458	Like service except flat base, 1-12 tin	4	18.7	28.	33.7
Service	70	... do	500	.458	Like service, except flat base, 1-12 tin.	5	12.6	23.1	26.3
						Mean.	15	22.7	28.2
Service, with lengthened chamber.	80	.. do	550	.458	Like service, 1-12 tin ..	1	14.5	29.5	32.9
	80	. do	550	.458	Like service, 1-12 tin ..	2	7.15	19.5	20.8
						Mean.	10.32	24.5	26.8
Long range	80	... do	500	.446	Patched, 1-19 tin	1	25.	15.3	29.3
Long range ..	80	... do	500	.446	Patched 1-19 tin	2	16.96	21.3	27.3
Long range ...	80	. do	500	.446	Patched, 1-19 tin	3	16.4	25.9	30.7
						Mean.	19.45	20.8	29.1

1,000 *yards range.—January* 26, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet Weight.	Bullet Caliber.	Bullet Kind.	No. of target.	Deviations. M H	Deviations. M V	Deviations. M. A.
	Grs.		*Grs*						
Service	70	Service	405	.458	Service, 1-16 tin	1	16.8	27.8	32.5
Service	70	....do	405	.458	Service, 1-16 tin	2	10.8	18.8	21.7
						Mean.	13.8	23.3	27 1
Service	70	Hazard, F. G. .	490	.458	Like service, 1-12 tin	1	14.34	19.5	24.2
Service	70	.. do	490	.458	Like service, 1-12 tin ...	2	9	15.9	18.3
						Mean.	11 67	17.7	21.2
18-inch twist, 3 grooves.	70	....do	490	.458	Like service, 1-12 tin ...	1	14.7	14.4	20.6
18-inch twist, 6 grooves.	70	....do	490	.458	Like service, 1-12 tin ...	1	18	14.1	22.9
Service	70	....do	500	.4555	Like service, 1-12 tin ...	1	21.3	15.32	26.2
Service	70	....do	500	.4555	Like service, 1-12 tin ...	2	18.2	19.9	26.9
						Mean.	19.7	17.61	26.5
18-inch twist, 3 grooves.	70	.. do	500	.4555	Like service, 1-12 tin	1	13.6	18.9	23.3
18-inch twist, 6 grooves.	70	....do	500	.4555	Like service, 1-12 tin .	1	12.6	12.5	17.8
Service ..	70	....do	500	.456	Flat point. No 2, 1-18 tin	1	16 7	22.3	27.9
18-inch twist, 3 grooves.	70	.. do	500	.456	Flat point, No. 2, 1-18 tin	1	18.3	22	28.6
18 inch twist, 6 grooves.	70	... do	500	.456	Flat point. No 2, 1-18 tin	1	15 8	26.8	31.1
Long range ...	80	.. do	500	.446	Patched, 1-19 tin	1	8.76	11.24	14.3
Long range	80	... do	500	.446	Patched, 1-19 tin	2	15.2	19 7	24 9
Long range	80	.. do	500	.446	Patched, 1-19 tin	3	16.6	17.4	24.1
						Mean	13.52	16.11	21.1

1,000 *yards range.—January* 30, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G.	490	.458	Like service, 1-12 tin	1	13.5	26.7	29.9
18-inch twist, 3 grooves	70	....do	490	.458	Like service, 1-12 tin	1	17.4	25.7	31
18-inch twist, 6 grooves.	70	....do	490	.458	Like service, 1-12 tin	1	18.7	23.9	30.3
Service	70	....do	500	.4555	Like service, 1-12 tin	1	14.3	25.7	29.4
18-inch twist, 3 grooves.	70	....do	500	.4555	Like service, 1-12 tin	1	16.1	21.4	26.8
Service	70	....do	500	.452	Flat point No. 1, 1-18 tin	1	21.8	18.2	28.4
18-inch twist, 3 grooves.	70	....do	500	.452	Flat point No. 1, 1-18 tin	1	11.5	16.7	20.3
18-inch twist, 6 grooves.	70	....do	500	.452	Flat point No. 1, 1-18 tin	1	14.7	23.9	28.1
Service	70	....do	500	.456	Flat point No. 2, 1-18 tin	1	62	20.4	21.3
18-inch twist, 3 grooves.	70	....do	500	.456	Flat point No. 2, 1-18 tin	1	10.6	17.6	20.5
18-inch twist, 6 grooves.	70	....do	500	.456	Flat point No. 2, 1-18 tin	1	19.2	13.7	23.6
Service, with lengthened chamber.	80	....do	550	.458	Like service, 1-12 tin	1	13.3	18.5	22.8
	80	....do	550	.458	Like service, 1-12 tin	2	14.1	19.8	24.3
						Mean.	13.7	19.1	23.6
Do	90	....do	550	.458	Like service, 1-12 tin	1	12.6	19.8	23.5
Do	90	....do	550	.458	Like service, 1-12 tin	2	10.9	17.9	21
Do	90	....do	550	.458	Like service, 1-12 tin	3	13.1	31	33.7
						Mean.	12.2	22.9	24.7

1,000 *yards range.—March* 4 *and* 5, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
March 4.	*Grs.*		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	12.3	22.7	25.8
Service	70	....do	500	.4555	Like service, 1-16 tin	2	18.7	28.5	34.1
Service	70	....do	500	.4555	Like service, 1-16 tin	3	9.1	16.9	19.2
Service	70	....do	500	.4555	Like service, 1-16 tin	4	17.4	11.3	20.7
Service	70	....do	500	.455	Like service, 1-16 tin	5	14.8	12.5	19.4
Service	70	....do	500	.4555	Like service, 1-16 tin	6	8	12.8	15.1
Service	70	....do	500	.4555	Like service, 1-16 tin	7	11.1	17.4	20.6
Service	76	....do	500	.4555	Like service, 1-16 tin	8	10.2	9.3	13.8
Service	70	....do	500	.4555	Like service, 1-16 tin	9	16.5	11	19.8
						Mean.	13.1	15.8	20.9
Service	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	14.2	23.6	27.5
Service	70	....do	480	.446	......do	2	16.4	19.4	25.4
						Mean.	15.3	21.5	26.4
March 5.									
Service	70	....do	500	.4555	Like service, 1-12 tin	1	15.8	7.9	17.7
Service	70	....do	500	.4555	Like service, 1-12 tin	2	16	18.9	24.8
						Mean.	15.9	13.4	21.2
Long-range	80	....do	500	.446	Patched, 1-19 tin	1	12.4	18.7	22.5

1,000 *yards range.—March* 6, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	70	Service	40	.458	Service, 1-16 tin	1	11.9	19.7	23.
Do	70	....do	405	.458	Service, 1-16 tin	2	12.6	26.9	29.7
Do	70	....do	405	.458	Service, 1-16 tin	3	20	14.3	24.6
Do	70	....do	405	.458	Service, 1-16 tin	4	16.1	14.8	21.9
						Mean.	15.1	18.9	24.8
Service	70	....do	405	.458	Service, 1-16 tin	1	11.3	21.6	24.4
Service, with lengthened chamber.	80	Hazard, F. G..	500	.4555	Like service, 1-12 tin...	1	12.2	13.7	18.3
Do	80	....do	500	.4555	Like service, 1 12 tin...	2	11.3	14.5	18.4
Do	80	....do	500	.4555	Like service, 1-12 tin...	3	14.5	10.8	18.1
Do	80	....do	500	.4555	Like service, 1-12 tin...	4	15.8	20.4	25.8
						Mean.	13.4	14.8	20.1

1,000 *yards range.—March* 12, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	65	Hazard, F. G..	500	.4555	Like service, 1-12 tin...	1	12.2	29.8	32.2
Service	65	....do	500	.4555	Like service, 1-12 tin...	2	14.7	29.8	33.2
Service	65	....do	500	.4555	Like service, 1-12 tin...	3	16.6	24.7	29.7
Service	65	....do	500	.4555	Like service, 1-12 tin...	4	11.8	34.3	36.2
						Mean.	13.8	29.6	32.8
Service	70	....do	500	.4555	Like service, 1-12 tin...	1	20.6	21.4	29.7
Service	70	....do	500	.4555	Like service, 1-12 tin...	2	17.72	19.5	26.3
Service	70	....do	500	.4555	Like service, 1-12 tin...	3	17.32	29.1	33.8
Service	70	....do	500	.4555	Like service, 1-12 tln...	4	10.48	30.28	31.9
						Mean.	16.53	25.7	30.4
Service, with lengthened chamber.	80	....do	500	.4555	Like service, 1-12 tin...	1	12.2	21.64	24.8
	80	....do	500	.4555	Like service, 1-12 tin...	2	10.1	23.0	25.1
Do	80	....do	500	.4555	Like service, 1-12 tin...	3	10.2	11.6	15.4
Do	80	....do	500	.4555	Like service, 1-12 tin...	4	13.8	26.2	29.2
						Mean.	11.39	20.61	23.6

1,000 *yards range.—March* 18, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G..	500	.4555	Like service, 1-12 tin....	1	18.0	20.3	27.1
Service	70	....do	500	.4555	Like service, 1-12 tin...	2	13.0	25.5	28.6
Service	70	....do	500	.4555	Like service, 1-12 tin....	3	13.3	18.8	23
Service	70	....do	500	.4555	Like service, 1-12 tin....	4	14.2	27.9	31.3
Service	70	....do	500	.4555	Like service, 1-12 tin....	5	11.1	32.1	33.9
						Mean.	13.9	24.9	28.8
Service, with lengthened chamber.	80	....do	500	.4555	Like service, 1-12 tin....	1	14.28	20.9	25.3
	80	....do	500	.4555	Like service, 1-12 tin....	2	14.5	20.8	25.4
Do........	80	....do	500	.4555	Like service, 1-12 tin....	3	7.9	18.0	19.6
Do........	80	....do	500	.4555	Like service, 1-12 tin....	4	15.8	14.5	21.4
Do........	80	....do	500	.4555	Like service, 1-12 tin....	5	15.6	15.72	22.1
						Mean.	13.61	17.98	22.8
Long-range	80	....do	500	.446	Patched, 1-19 tin........	1	5.78	28.4	29
Long-range	80	....do	500	.446	Patched, 1-19 tin........	2	9.5	22.3	24.2
						Mean.	7.64	25.3	26.6

1,000 *yards range.—March* 23, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G..	500	.4555	Like service, 1-12 tin....	1	12.6	22.4	25.7
Service	70	....do	500	.4555	Like service, 1-12 tin....	2	13.2	22.7	26.2
Service	70	....do	500	.4555	Like service, 1-12 tin....	3	11.4	23.5	26.1
Service	70	....do	500	.4555	Like service, 1-12 tin....	4	13.1	24.4	27.7
Service	70	....do	500	.4555	Like service, 1-12 tin....	5	12	21.7	24.8
						Mean.	12.5	22.9	26.1
Service, with lengthened chamber.	80	....do	500	.4555	Like service, 1-12 tin....	1	12.8	17.4	21.6
	80	....do	500	.4555	Like service, 1-12 tin....	2	21.5	25.9	33.4
Do	80	....do	500	.4555	Like service. 1-12 tin....	3	17.2	23.7	29.3
Do	80	....do	500	.4555	Like service, 1-12 tin....	4	14.8	25	39.1
Do	80	....do	500	.4555	Like service, 1-12 tin....	5	13.2	31.5	34.2
						Mean.	15.9	24.7	29.5

1,000 *yards range.—April* 1, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	20	23.3	30.7
Service	70	....do	500	.4555	Like service, 1-16 tin	2	12.3	29	31.5
Service	70	....do	500	.4555	Like service, 1-16 tin	3	21.4	20.6	29.7
Service	70	....do	500	.4555	Like service, 1-16 tin	4	19	16.70	25.3
Service	70	....do	500	.4555	Like service, 1-16 tin	5	22.9	14	26.8
						Mean.	19.1	20.72	28.8
Service, with lengthened chamber.	80	....do	500	.4555	Like service, 1-16 tin	1	10.8	21	23.6
	80	....do	500	.4555	Like service, 1-16 tin	2	15.4	17.3	23.2
Do	80	....do	500	.4555	Like service, 1-16 tin	3	16.3	13	20.8
Do	80	....do	500	.4555	Like service, 1-16 tin	4	23.3	15.2	27.8
						Mean.	16.4	16.61	23.9

1,000 *yards range.—April* 21 *and* 22, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullets. Weight.	Bullets. Caliber.	Bullets. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
April 21.	*Grs.*		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	14.1	22.4	26.5
Service	70	....do	500	.4555	Like service, 1-16 tin	2	12.8	10.3	16.4
Service	70	....do	500	.4555	Like service, 1-16 tin	3	15.2	19.9	25
Service	70	....do	500	.4555	Like service, 1-16 tin	4	15.4	28.2	32.1
Service	70	....do	500	.4555	Like service, 1-16 tin	5	22.2	24.4	33
						Mean.	15.9	21	26.6
Service, with lengthened chamber.	80	....	500	.4555	Like service, 1-16 tin	1	8.6	9.2	12.6
	80	... do	500	.4555	Like service, 1-16 tin	2	10.5	15.7	18.9
Do	80	....do	500	.4555	Like service, 1-16 tin	3	17.5	15.9	23.6
Do	80	....do	500	.4555	Like service, 1-16 tin	4	11.3	16.3	19.8
Do	80	....do	500	.4555	Like service, 1-16 tin	5	19.8	9.5	22
						Mean.	13.5	13.3	19.4
April 22.	*Grs.*								
Service	70	....do	500	.4555	Like service, 1-16 tin	1	11.2	15.8	19.4
Service	70	....do	500	.4555	Like service, 1-16 tin	2	16.1	22.9	28
Service	70	....do	500	.4555	Like service, 1-16 tin	3	12	11.6	16.7
						Mean.	13.1	16.8	21.4
Service, with lengthened chamber.	80	....do	500	.4555	Like service, 1-16 tin	1	11.7	17.7	21.2
	80	Oriental	500	.458	Like service, machine-made, 1-17 tin.	2	18.7	20.2	27.5
						Mean.	15.2	18 9	24.3

1,000 *yards range.—May* 4, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	17.7	20	26.7
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	15.9	12.7	20.3
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	13.4	15.9	20.8
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	11.5	13.6	17.8
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	12.9	16.7	21.1
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	17	22.2	27.9
						Mean.	14.9	19.4	24.5
Service with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	20.7	24.6	32.2
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	14.5	13.6	18.9
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	12.3	22.4	25.6
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	14.1	20.4	24.8
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	9.4	19.5	21.6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	12.4	16.4	20.6
						Mean.	10.9	17.9	21.1

First four targets, light head wind; next six targets, stiff head wind; last two targets, very strong head wind.

1,000 *yards range.—May* 5, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	14.2	20.4	24.9
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	15.5	16	22.3
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	13.1	17.6	21.9
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	12.9	24.2	27.4
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	14.5	18.4	23.4
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	17	10.8	20.1
						Mean.	15.7	14.6	21.7
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	23.8	28.2	36.9
	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	25.2	18.3	31.1
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin,	1	12	14.2	18.6
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	22.2	14.1	26.1

First six targets, stiff breeze from front; last four targets, strong head wind

1,000 *yards range.—May* 6, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	16.4	16	22.9
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	15.4	21.7	26.6
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	15	20.2	25.2
Service	70	Hazard, F, G.	500	.458	Frankford, like service, 1-17 tin.	1	13.5	29.8	32.7
Service	70	...do	500	.4555	Springfield, like service, 1-16 tin.	1	12.4	23.1	26.2
Service	70	...do	500	.4555	Springfield, like service, 1-16 tin.	2	16.7	14.6	22.2
						Mean.	14.5	18.8	24.2
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	17.2	21.6	27.6
	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	10.4	17.8	20.6
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	23.8	14	27.6

First six targets, light breeze from front; last three targets, strong breeze from right and front.

1,000 *yards range.—May* 7, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	13.4	27.2	30.3
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	11.6	22.2	25.1
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	20.1	26.8	33.5
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	13.2	34.9	37.3
Service	70	...do	500	.4555	Springfield, like service, 1-16 tin.	1	16.6	19.9	25.9
Service with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	11.4	16.4	20
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	16.6	26.9	31.6
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	17.4	22.6	28.5
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	25.2	37.3	43.9
Do	80	...do	500	.4555	Springfield, like service, 1-16 tin.	1	22.9	19.6	30.1
Do	80	...do	500	.4555	Springfield, like service, 1.16 tin.	2	11.6	11	16.
						Mean.	17.2	15.3	23

Calm.

1,000 *yards range.—May* 8, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	27.7	21.1	34.8
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	12.1	18.7	22.3
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	12.2	26.3	29
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	13.4	12.6	18.4
Service	70	do	500	.4555	Springfield, like service, 1-16 tin.	1	8.2	11.2	13.9
Service	70	do	500	.4555	Springfield, like service, 1-16 tin.	2	16.2	30.4	34.5
						Mean.	12.2	20.8	24.4
Service with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	30.5	22.9	38.1
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	14.4	9.1	17
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	19.7	26.4	32.9
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	21.8	29.5	36.7
Do	80	do	500	.4555	Springfield, like service, 1-16 tin.	1	14.6	16.3	21.9
Do	80	do	500	.4555	Springfield, like service, 1-16 tin.	2	23.9	17.1	29.4
						Mean.	19.2	16.7	25.7

First five targets, light breeze from the right and front; sixth target, strong breeze; the last six targets strong wind.

1,000 *yards range.—May* 10, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	16.4	12	20.3
Service	70	do	500	.458	Frankford, like service, 1-12 tin.	2	16.2	26.6	31.1
Service	70	Hazard, G. F.	500	.458	Frankford, like service, 1-12 tin.	1	14.9	17.5	23
Service	70	do	500	.458	Frankford, like service, 1-12 tin.	2	30.8	20.2	36.8
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	18.4	32.3	37.2
Service	70	do	500	.458	Frankford, like service, 1-17 tin.	2	16.8	23.2	28.6
Service with lengthened chamber.	80	do	500	.458	Frankford, like service, 1-12 tin.	1	22.9	28.5	36.6
Do	80	do	500	.458	Frankford, like service, 1-12 tin.	2	19.4	21.1	28.7
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	21	10.5	23.5
Do	80	do	500	.458	Frankford, like service, 1-12 tin.	2	18.6	20	27.3

The first six targets, fresh breeze from the front and right; the last four targets, stiff breeze from the right and front.

1,000 *yards range.—May* 11, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	11	25.3	27.6
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	15.6	34.3	37.7
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	11	17.9	21
Service	70	....do	500	.458	Frankford, like service. 1-12 tin.	2	14.2	12.7	19
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	7.8	22.1	23.4
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	8.5	19.7	21.5
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	14.9	13.8	20.3
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	10.4	33.2	34.8
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	9.5	12.7	15.9
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	13.6	20.2	24.4
Service with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	25.9	17.6	31.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	8	24.1	25.4
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	8.8	29	30.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	9.9	17.3	19.9
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	12.8	20.5	24.2
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	10.6	28.6	30.5
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	18.4	20.4	27.5
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	11.6	27.8	30.1
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	10.1	15.1	18.2
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	11.1	11.6	16

Stiff breeze from the front.

1,000 *yards range.—May* 12, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	11.7	28	30.3
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	13.1	24.4	27.7
Service	70	Oriental	500	.478	Frankford, like service, 1-12 tin.	1	10.5	26	28
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	18.2	21.7	28.6
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	16.9	22.2	27.9
Service	70	....do	500	.4555	Springfield, like serv- 1-16 tin.	2	14.3	23.7	27.7
						Mean.	1 5.6	22.9	27.8
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service 1-12 tin.	1	25.1	13.8	28.6
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	15.5	25.7	30
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	11.7	19.8	23
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	20.4	29.4	35.8
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	16	16.6	23.1
Do	80	....do	500	.4555	Frankford, like service, 1-16 tin.	2	21.3	8.4	22.9
Do	80	....do	500	.4555	Frankford, like service, 1-16 tin.	3	15.4	10.2	18.5
						Mean.	17.5	11.7	21.5

First five targets calm; the sixth target, light breeze from the right; the next four targets, stiff breeze from the right; the last three targets, strong wind from the right.

1,000 *yards range.—May* 13, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	11.6	37.3	39.1
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	15.9	25.3	27.8
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	19.1	18.2	26.4
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	22	39.9	45.6
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	9.8	18.4	20.8
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	22.2	24.5	33.1
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	18.7	27.6	33.3
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	23.2	26.2	35
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	16.6	29.9	34.2
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	17.3	20.3	26.7

First two targets, calm; next three targets, light breeze; last five targets, strong wind.

1,000 *yards range.—May* 14, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	14.5	26.2	29.9
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	20.9	19.8	28.8
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	1	30.1	28.2	41.2
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	22.3	32.6	39.5
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	1	9.8	30.9	32.4
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	18.4	26.9	32.6
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	1	16.5	19.9	25.8
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	13	30.9	33.5
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	14.6	15.3	21.1
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	19.5	19.5	27.6
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	12.2	21.4	24.6
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	18.4	29.1	26.5

Light breeze from the left.

1,000 *yards range.—May* 15, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	13.26	27.3	30.3
Service	70	....do	500	.458	Frankford, like service, 1-12 tin,	2	16.2	26.2	30.8
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	1	25	27.4	37.1
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	1	27.9	19.18	33.8
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	17.16	30.5	34.9
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	1	20.2	34.6	40.1
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	16.9	24.64	29.8
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	31.24	24.9	39.9
Service, with lengthened chamber.	80	....do	500	.458	Frankford, like service, 1-12 tin,	1	27.3	33.7	43.4
Do..........	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	22.1	27.56	35.3

First eight targets, strong wind from right and rear; last two targets, very strong wind.

1,000 *yards range.—May* 18, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		Grs.						
18-inch twist, 3 grooves.	70	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	17.9	27.7	33
Do	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	9.6	16.4	19
						Mean.	13.7	22	26
Do	70	....do	500	.458	Frankford, like service, 1-17 tin.	1	12.9	25.9	28.9
Do	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	9.3	28.4	29.9
						Mean.	11.1	27.1	29.4
Do	70	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	12.8	16.2	20.6
Do	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	18.8	35.3	40
						Mean.	15.8	25.8	30.3
Do	70	Hazard, F. G..	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	8	11.7	14.2
Do	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	2	16.1	20	25.7
Do	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	3	8.4	29	30.2
						Mean.	10.8	20.2	23.4
Service	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	23.7	12.5	26.8
Service	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	2	16.5	18.5	24.8
						Mean.	20.1	15.5	25.8
Service	70	....do	500	.446	Frankford, like service, 1-17 tin.	1	21.6	22.3	31
Service, with lengthened chamber.	75	Dupont	500	.446	Frankford, like service, 1-12 tin.	1	7.1	19.3	20.6

The first four targets and second last, calm; all other targets, light breeze from left and rear.

1,000 *yards range.—May* 25, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	14.9	25.9	29.9
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	2	10.2	19.4	21.9
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	3	10.3	25.2	27.2
Do	75	... do	500	.458	Frankford, like service, 1-12 tin.	4	15.1	21.4	26.2
						Mean.	12.6	23	26.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	1	8.7	16.2	18.4
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	15.2	25.7	29.9
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	13.7	24.8	28.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	11.6	29.6	31.8
						Mean.	12.3	24.1	27.1
Do	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	6.3	18.8	19.8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	14.1	17.9	22.8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	12.9	23.4	26.7
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	16.5	18.1	24.5
						Mean.	12.4	19.5	23.4

Calm.

800 *yards range.—May* 24, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	10.2	16.2	19.1
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	9.4	12	15.2
						Mean.	9.8	14.1	17.1
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	1	9.8	13.9	17
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	10.7	9	14
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	3	9.3	15.5	18.1
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	4	7.8	14	16
						Mean.	9.4	13.1	16.3

Light breeze from the left and rear.

800 *yards range.—May* 24, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	12.1	12.3	17.3
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	2	13.4	16.5	21.2
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	3	14.5	16.7	22.1
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	4	17	11.7	20.6
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	5	10.3	15.9	18.9
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	6	5.3	10.4	11.7
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	7	13.1	11.2	17.2
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	8	5.2	9.7	11
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	9	8.9	15.6	18
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	10	14.2	14.5	20.3
Do	75	...do	500	.458	Frankford, like service, 1-12 tin.	11	10.6	14.5	18
						Mean.	11.4	13.6	17.8
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	1	15.6	18.9	24.5
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	2	9.4	18.4	20.7
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	3	16.4	15.9	22.8
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	4	17.0	19.8	26.1
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	5	9.2	15.9	18.6
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	6	11.8	9.6	15.2
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	7	9.4	6.6	11.5
Do	80	...do	500	.458	Frankford, like service, 1-12 tin.	8	11.3	18.8	21.9
						Mean.	12.5	14.5	20.1

Light breeze from the left and rear.

800 *yards range.—May* 27, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	75	Dupont......	500	.458	Frankford, like service, 1-12 tin.	1	6.4	8.2	10.4
Do.........	75	....do.........	500	.458	Frankford, like service, 1-12 tin.	2	8.8	7.6	11.6
Do.........	75	....do.........	500	.458	Frankford, like service, 1-12 tin.	3	15.4	11.6	19.3
						Mean.	10.2	9.1	13.8
Do.........	80	....do.........	500	.458	Frankford, like service, 1-12 tin.	1	12	12.2	17.1
Do.........	80	....do.........	500	.458	Frankford, like service, 1-12 tin.	2	8.1	24.9	26.2
						Mean.	10	18.5	21.6
Do.........	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	10.4	15.1	18.3
Do.........	80	....do.........	500	.458	Frankford, like service, 1-12 tin.	2	12.3	6.	13.7
Do.........	80	....do.........	500	.458	Frankford, like service, 1-12 tin.	3	12.4	16.5	20.6
Do.........	80	....do.........	500	.458	Frankford, like service, 1-12 tin.	4	10.8	14.2	17.8
						Mean.	11.5	12.9	17.6
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-12 tin.	1	10	13.6	16.9
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-12 tin.	2	12	12.5	17.3
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-12 tin.	3	12.9	8.9	15.7
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-12 tin.	4	11.5	19.8	22.9
						Mean.	11.6	13.7	19.2

Calm.

800 *yards range.—June* 12, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Springfield, like service, 1-16 tin.	1	15.3	8.4	17.4
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	10	11.4	15.2
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	3	9.9	6.8	12
						Mean.	11.7	13.3	14.9
Service, with lengthened chamber.	80	....do	500	.4455	Springfield, like service, 1-16 tin.	1	9.4	18.4	20.7
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	6.8	12.5	14.2
						Mean.	8.1	15.4	17.4

Light breeze from the right and rear.

800 *yards range.—June* 16, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
18-inch twist, 6 grooves, with lengthened chamber.	80	Hazard, F G.	500	.4555	Springfield, like service, 1-16 tin.	1	12.8	10.9	16.8
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin,	2	11.4	13.4	17.6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	3	9.7	7.	12.
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	4	13.5	10.7	17.2
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	5	5.5	7.8	9.5
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	6	9.0	12.4	15.3
Do	80	....do	500	.4555	Springfield, like service, 1-15 tin.	7	10.9	12.9	16.9
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	8	13.	9.7	16.2
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	9	12.5	13.8	18.6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	10	10.2	10.6	14.7
						Mean..	10.8	10.9	15.5

Stiff breeze from right and rear.

800 *yards range.—June* 18 *and* 22, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
June 18.	*Grs.*		*Grs.*						
Long-range	80	Hazard, F. G..	550	.446	Patched, 1-19 tin........	1	10.9	9.9	14.7
Long-range	80	....do	550	.446	Patched, 1-19 tin	2	9.6	10.6	14.3
Long-range	80	....do	550	.446	Patched, 1-19 tin........	3	7.4	18.8	20.2
Long-range	80	... do	550	.446	Patched, 1-19 tin........	4	10.8	13.4	17.2
Long-range	80	....do	550	.446	Patched, 1-19 tin........	5	9.	12.7	15.6
						Mean..	9.5	13.1	16.4
June 22. Service, with lengthened chamber.	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	9.1	10.9	14.2
Do..........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	12.9	9.1	15.8
Do..........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	3	8.9	12.6	15.4
Do..........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	4	12.1	6.2	13.6
Do..........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	5	8.9	12.2	15.1
Do..........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	6	15.3	15.1	21.5
						Mean..	11.2	11.	15.9

First five targets, calm; the others, very strong wind from the left.

500 *yards range.—December* 1, 16, *and* 17, 1879.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
December 1.	*Grs.*		*Grs.*						
Service	70	Hazard, F. G.	500	.458	Used at Sandy Hook; full at point, 1-12 tin.	1	12.6	11.3	16.9
18-inch twist, 3 grooves.	70	....do	500	.458	......do	1	9.25	8.92	12.9
18-inch twist, 6 grooves.	70	....do	500	.458	......do	1	4.65	9.8	10.9
Service	70	....do	500	.458	Shoulder at front of shell, 1-12 tin.	1	9.7	8.5	12.9
18-inch twist, 3 grooves.	70	....do	500	.458	Shoulder at front of shell, 1-12 tin.	1	8.3	6.5	10.5
18-inch twist, 6 grooves.	70	....do	500	.458	Shoulder at front of shell, 1-12 tin.	1	10.4	9.5	14.1
December 16.									
Service	70	Hazard, F. G.	500	.458	Like service, except flat base, 1-12 tin.	1	6.36	4.	7.5
18-inch twist, 3 grooves.	70	....do	500	.458	Like service, except flat base, 1-12 tin.	1	6.92	8.76	11.1
18-inch twist, 6 grooves.	70	....do	500	.458	Like service, except flat base, 1-12 tin.	1	5.	6.04	7.9
Service	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	2.88	8.56	9.99
18-inch twist, 3 grooves.	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	4.8	5.76	7.5
18-inch twist, 6 grooves.	70	....do	480	.446	Long-range Springfield, grooved and lubricated, 1-12 tin.	1	5.44	6.52	8.49
December 17.									
Service	70	Hazard, F. G.	500	.458	Like service, except flat base, 1-12 tin.	1	4.5	10.56	11.5
Service	70	....do	500	.458	Like service, except flat base, 1-12 tin.	2	6.1	7.3	9.5
						Mean..	5.3	8.93	10.5
18-inch twist, 3 grooves.	70	Hazard, F. G.	500	.458	Like service, except flat base, 1-12 tin.	1	7.	6.3	9.4
18-inch twist, 3 grooves.	70	....do	500	.458	Like service, except flat base, 1-12 tin.	2	7.4	10.	12.4
						Mean..	7.2	8.1	10.9
18-inch twist, 6 grooves.	70	Hazard, F. G.	500	.458	Like service, except flat base, 1-12 tin.	1	8.76	5.4	10.3
18-inch twist, 6 grooves.	70	....do	500	.458	Like service, except flat base, 1-12 tin.	2	4.14	5.	6.49
						Mean..	6.45	5.2	8.39
Service	70	Hazard, F. G.	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	7.6	6.64	10.1
18-inch twist, 3 grooves.	70	....do	480	.446	......do	1	3.76	3.16	4.91
18-inch twist, 6 grooves.	70	....do	480	.446	......do	1	5.16	7.	8.7
Service	70	....do	490	.458	Like service, 1-12 tin	1	4.7	3.54	5.88
18-inch twist, 3 grooves.	70	....do	490	.458	Like service, 1-12 tin	1	3.32	5.3	6.25
18-inch twist, 6 grooves.	70	....do	490	.458	Like service, 1-12 tin	1	7.44	6.64	10.

500 yards range.—December 19, 23, 1879, *and February* 18, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
December 19.	*Grs.*		*Grs.*						
Service	70	Service	405	.458	Service, 1-16 tin	1	6.1	11.92	13.4
Service	70	....do	405	.458	Service, 1-16 tin	2	3.	6.52	7.18
						Mean..	4.5	9.22	10.29
Service	70	Hazard, F. G.	500	.458	Like service, except flat base, 1-12 tin.	1	6.5	4.14	7.71
18-inch twist, 3 grooves.	70	....do	500	.458	Like service, except flat base, 1-12 tin.	1	6.56	5.6	8.62
18-inch twist, 6 grooves.	70	....do	500	.458	Like service, except flat base, 1-12 tin.	1	14.56	7.5	16.4
Service	70	... do	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	6.8	2.14	7.13
18-inch twist, 3 grooves.	70	....do	480	.446	......do	1	5.6	10.9	12.25
18-inch twist, 6 grooves.	70	....do	480	.446	......do	1	5.9	6.44	8.73
Service	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	12.3	5.7	13.5
18-inch twist, 6 grooves.	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	8.2	9.4	12.5
Long-range	80	....do	500	.446	Patched, 1-19 tin	1	4.34	6.3	7.65
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	5.4	5.9	8.
						Mean..	4.87	6.1	7.82
December 23.			*Grs.*						
Service	70	Service	405	.458	Service, 1-16 tin	1	5.36	8.44	10.
Service	70	Hazard, F. G.	490	.458	Like service, 1-12 tin	1	4.76	6.72	8.23
18-inch twist, 3 grooves.	70	... do	490	.458	Like service, 1-12 tin	1	5.5	13.7	14.7
18-inch twist, 6 grooves.	70	....do	490	.458	Like service, 1-12 tin	1	4.7	5.26	7.05
Long-range	80	... do	500	.446	Patched, 1-19 tin	1	3.4	3.84	5.13
18-inch twist, 3 grooves.	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	6.4	8.1	10.3
18-inch twist, 6 grooves.	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	21.3	8.3	22.8
February 18.									
Service	70	Service	405	.458	Service, 1-16 tin	1	4.3	5.4	6.9
Service	70	....do	405	.458	Service, 1-16 tin	2	8.1	5.8	9.96
Service	70	....do	405	.458	Service, 1-16 tin	3	6.56	9.	11.2
Service	70	....do	405	.458	Service, 1-16 tin	4	7.58	4.56	8.85
						Mean..	6.63	6.19	9.23
Service, with lengthened chamber.	70	....do	405	.458	Service, 1-16 tin	1	7.6	7.8	10.9
Do	70	....do	405	.458	Service, 1-16 tin	2	7.56	7.56	10.7
Do	70	....do	405	.458	Service, 1-16 tin	3	4.68	5.72	7.39
Do	70	....do	405	.458	Service, 1-16 tin	4	5.2	7.3	8.96
						Mean..	6.26	7.09	9.49
Service, with lengthened chamber.	80	Hazard, F. G.	550	.458	Like service, 1-12 tin	1	4.08	6.32	7.52
Do	80	....do	550	.458	Like service, 1-12 tin	2	4.44	5.92	7.4
Do	80	....do	550	.458	Like service, 1-12 tin	3	4.32	5.8	7.23
Do	80	....do	550	.458	Like service, 1-12 tin	4	6.7	5.28	8.53
						Mean..	4.88	5.83	7.67

500 yards range.—March 6 *and* 8, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
March 6. Service, with lengthened chamber.	70	Service	405	.458	Service, 1-16 tin	1	7.5	7.1	10.3
Do	70	....do	405	.458	Service, 1-16 tin	2	5.7	11.1	12.5
Do	70	....do	405	.458	Service, 1-16 tin	3	5.2	8.3	9.79
Do	70	....do	405	.458	Service, 1-16 tin	4	5.7	4.3	7.14
						Mean..	6.0	7.7	9.93
Service	70	Service	405	.458	Service, 1-16 tin	1	8.3	8.4	11.8
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	7.3	6.8	9.98
Do	80	....do	500	.4555	Like service, 1-12 tin	2	4.4	6.4	7.83
Do	80	....do	500	.4555	Like service, 1-12 tin	3	12.6	10.6	16.5
Do	80	....do	500	.4555	Like service, 1-12 tin	4	3.2	4.6	5.6
Do	80	....do	500	.4555	Like service, 1-12 tin	5	5.4	8.5	10.1
						Mean..	6.6	7.4	10.
March 8. Service	70	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	5.7	5.3	7.78
Service	70	....do	500	.4555	Like service, 1-12 tin	3	4.4	9.2	10.2
Service	70	....do	500	.4555	Like service, 1-12 tin	3	10.1	8.4	13.2
						Mean..	6.7	7.6	10.39
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	4.4	4.4	6.3
Service	70	....do	500	.4555	Like service, 1-16 tin	2	6.	5.2	7.9
						Mean..	5.2	4.8	7.1
Service	65	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	5.9	10.	11.6
Service	65	....do	500	.4555	Like service, 1-12 tin	2	4.5	7.7	8.91
						Mean..	5.2	8.8	10.25
Service	70	Hazard, F. G.	480	.446	Long-range Springfield, grooved and lubricated, 1-19 tin.	1	9.1	9.5	13.1
Long-range	80	Hazard, F. G.	500	.446	Patched, 1-19 tin	1	5.4	4.4	6.97
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	4.4	6.5	7.85
						Mean..	4.9	5.4	7.41

50 *yards range.—March* 18, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M.H.	Deviations. M.V.	Deviations. M.A.
March 18.	*Grs.*		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	9.88	11.38	14.96
Service	70	....do	500	.4555	Like service, 1-12 tin	2	5.76	8.76	10.39
Service	70	....do	500	.4555	Like service, 1-12 tin	3	6.96	7.3	10.05
Service	70	....do	500	.4555	Like service, 1-12 tin	4	9.3	11.04	14.45
Service	70	....do	500	.4555	Like service, 1-12 tin	5	6.2	8.18	10.1
						Mean	7.58	9.33	11.99
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	4.9	5.32	7.21
Do	80	....do	500	.4555	Like service, 1-12 tin	2	3.8	7.64	8.48
Do	80	....do	500	.4555	Like service, 1-12 tin	3	5.12	7.3	8.88
Do	80	....do	500	.4555	Like service, 1-12 tin	4	5.2	7.0	8.72
Do	80	....do	500	.4555	Like service, 1-12 tin	5	6.34	7.16	9.48
						Mean	5.7	6.88	8.55
Long-range	80	Hazard, F. G.	500	.446	Patched, 1-19 tin	1	7.0	4.6	8.36
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	7.3	7.8	10.67
						Mean	7.1	6.1	9.51

500 *yards range.—March* 22, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M.H.	Deviations. M.V.	Deviations. M.A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	7.9	8.	11.2
Service	70	....do	500	.4555	Like service, 1-12 tin	2	11.4	6.8	13.3
Service	70	....do	500	.4555	Like service, 1-12 tin	3	8.8	5.6	10.4
Service	70	....do	500	.4555	Like service, 1-12 tin	4	7.8	6.4	10.1
Service	70	....do	500	.4555	Like service, 1-12 tin	5	6.8	4.8	8.32
						Mean	8.5	6.3	10.66
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	7.6	4.3	8.73
Do	80	....do	500	.4555	Like service, 1-12 tin	2	5.3	4.6	7.02
Do	80	....do	500	.4555	Like service, 1-12 tin	3	5.5	5.	7.43
Do	80	....do	500	.4555	Like service, 1-12 tin	4	4.2	7.	8.16
Do	80	....do	500	.4555	Like service, 1-12 tin	5	5.04	2.96	5.85
						Mean	5.53	4.77	7.44

500 yards range.—March 27 and 29, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
March 27.	*Grs.*		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	4.9	8.7	9.98
Service	70	....do	500	.4555	Like service, 1-16 tin	2	4.1	5.	6.46
Service	70	....do	500	.4555	Like service, 1-16 tin	3	2.8	7.6	8.1
Service	70	....do	500	.4555	Like service, 1-16 tin	4	7.1	5.8	9.17
Service	70	....do	500	.4555	Like service, 1-16 tin	5	8.4	7.3	11.1
						Mean	5.5	6.9	8.96
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	5.1	5.	7.2
Do	80	....do	500	.4555	Like service, 1-16 tin	2	6.1	6.4	9.4
Do	80	....do	500	.4555	Like service, 1-16 tin	3	2.7	8.9	9.3
Do	80	....do	500	.4555	Like service, 1-16 tin	4	4.	4.5	6.02
Do	80	....do	500	.4555	Like service, 1-16 tin	5	3.9	6.4	7.5
						Mean	4.4	6.6	7.9
March 29.									
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	5.1	5.4	7.43
Do	80	....do	500	.4555	Like service, 1-16 tin	2	5.44	4.2	6.87
Do	80	....do	500	.4555	Like service, 1-16 tin	3	4.7	7.5	8.85
Do	80	....do	500	.4555	Like service, 1-16 tin	4	4.44	4.5	6.32
Do	80	....do	500	.4555	Like service, 1-16 tin	5	7.4	5.4	9.16
						Mean	5.42	5.4	7.73
*March 29.**									
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	4.96	6.5	8.2
Service	70	....do	500	.4555	Like service, 1-16 tin	2	13.8	6.	15.
Service	70	....do	500	.4555	Like service, 1-16 tin	3	8.7	5.6	10.3
Service	70	....do	500	.4555	Like service, 1-16 tin	4	6.1	10.6	12.2
Service	70	....do	500	.4555	Like service, 1-16 tin	5	10.2	11.6	15.4
						Mean	8.75	8.1	12.2

* Very heavy wind.

500 *yards range.—April* 5, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-12 tin	1	7.3	3.8	8.23
Service	70	....do	500	.4555	Like service, 1-12 tin	2	5.3	5.4	7.57
						Mean	6.3	4.6	7.9
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	6.4	4.9	8.06
Do	80	....do	500	.4555	Like service, 1-16 tin	2	9.1	8.9	12.7
						Mean	7.7	6.9	10.38
Do	80	Service	500	.458	Frankford, like service, 1-12 tin.	1	5.6	11.04	12.7
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	7.9	7.56	10.9
						Mean.	6.7	9.30	11.8

500 *yards range.—April* 16, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Service	405	.458	Service	*1	5.9	7.7	9.7
Service	70	....do	405	.458	Service	†2	5.	6.7	8.3
Service	70	....do	405	.458	Service	‡3	5.2	4.8	7.
Service	70	....do	405	.458	Service	‖4	7.1	4.9	8.6
						Mean	5.8	6.0	8.4
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	*1	7.3	6.6	9.8
Service	70	....do	500	.4555	Like service, 1-16 tin	2	4.5	4.3	6.2
Service	70	....do	500	.4555	Like service, 1-16 tin	†3	7.2	7.4	10.3
Service	70	....do	500	.4555	Like service, 1-16 tin	4	5.5	8.7	10.3
Service	70	....do	500	.4555	Like service, 1-16 tin	‡5	9.7	5.1	11.0
Service	70	....do	500	.4555	Like service, 1-16 tin	6	8.3	8.2	11.7
Service	70	....do	500	.4555	Like service, 1-16 tin	‖7	8.	5.7	9.8
Service	70	....do	500	.4555	Like service, 1-16 tin	8	7.1	6.4	9.5
						Mean	7.2	6.5	9.8

* Hare. † M. W. Bull. ‡ Cranston. ‖ F. R. Bull.

500 *yards range.—April* 30, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	7.9	3.4	8.6
Service	70	....do	500	.4555	Like service, 1-16 tin	2	7.2	8.3	11.
Service	70	....do	500	.4555	Like service, 1-16 tin	3	12.5	6.4	14.
Service	70	....do	500	.4555	Like service, 1-16 tin	4	4.4	7.1	8.3
						Mean	8.	6.3	10.5
Service, with lengthened chamber.	80	Hazard, F. G.	500	.4555	Like service, 1-16 tin	1	7.7	5.6	9.5
Do	80	....do	500	.4555	Like service, 1-16 tin	2	5.1	3.9	6.4
Do	80	....do	500	.4555	Like service, 1-16 tin	3	5.1	4.1	6.5
Do	80	....do	500	.4555	Like service, 1-16 tin	4	5.4	3.3	6.3
						Mean	7.7	4.2	7.2
Long-range	80	Hazard, F. G.	500	.446	Patched, 1-19 tin	1	6.2	6.9	9.3
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	4.2	7.9	8.9
Long-range	80	....do	500	.446	Patched, 1-19 tin	3	5.2	6.2	8.1
Long-range	80	....do	500	.446	Patched, 1-19 tin	4	7.4	6.7	10.
						Mean	5.7	6.9	9.1
Service	67	....do	500	.4555	Like service, 1-16 tin	1	5.9	6.4	8.7

500 *yards range.—May* 3, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	6.4	5.	8.1
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	4.9	7.1	8.6
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	5.4	8.	9.7
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	6.1	6.2	8.7
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	4.2	4.8	6.4
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	8.7	8.3	12.
						Mean	6.4	6.5	9.2
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	4.9	10.	11.2
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin,	1	5.6	5.2	7.6
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	6.8	6.2	9.2
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	5.6	7.	9.
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin,	1	5.2	4.8	7.1
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	4.9	8.	9.4
						Mean	5.	6.4	8.2

Light wind from right and rear.

500 *yards range.—May* 8, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	7.6	5.6	9.4
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin,	1	7.8	9.9	12.6
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	6.9	8.8	11.2
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	7.8	5.6	9.6
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	4.4	9.7	10.6
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	2.9	7.4	8.
						Mean	3.6	8.5	9.3
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	5.7	6.1	8.4
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	9.7	6.1	11.5
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	6.6	10.	12.
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	11.4	6.8	13.3
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	6.5	5.9	9.3
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	6.3	5.6	8.4
						Mean	6.4	5.7	8.8

Light breeze from right and rear.

500 *yards range.—May* 11, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	5.9	10.2	11.8
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	7.	9.1	11.5
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	3	3.	4.8	5.7
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	11.	9.5	14.5
Service with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	9.	9.3	12.9
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	8.5	7.4	11.3
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	8.4	5.9	10.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	8.1	6.3	10.2
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	6.1	7.4	9.6

Fresh breeze from left and rear.

500 *yards range.—May* 12, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	6.1	5.6	8.3
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	5.1	4.1	6.5
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	12.6	6.7	14.3
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	4.4	6.	7.4
Service	70	...do	500	.4555	Springfield, like service, 1-16 tin.	1	4.	5.3	6.6
Service	70	...do	500	.4555	Springfield, like service, 1-16 tin.	2	7.	8.4	10.9
						Mean	5.5	6.8	8.8
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	10.4	6.3	12.2
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	5.4	8.3	9.9
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin,	1	8.3	8.8	12.1
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	9.3	9.2	13.1
Do	80	...do	500	.4555	Springfield, like service, 1-16 tin.	1	7.8	6.3	10.
Do	80	...do	500	.4555	Springfield, like service, 1-16 tin.	2	6.	5.2	7.9
						Mean	6.9	5.8	8.9

Strong wind from the left.

500 *yards range.—May* 15, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	4.5	10.2	11.1
Service	70	Hazard, F. G..	500	.458	Frankford, like service, 1-17 tin.	1	8.3	7.	10.9
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	9.2	7.2	11.7
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	3	8.3	4.2	9.3
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	5.7	4.2	7.1
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	7.6	4.8	9.
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	10.	12.	15.6
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	8.	12.2	14.6
Do	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	10.3	4.9	11.4
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	13.6	9.5	16.6
Do	80	Oriental	500	.468	Frankford, like service, 1-17 tin.	1	6.2	4.3	7.5
Do	80	....do	500	.4555	Frankford, like service, 1-17 tin.	2	9.9	5.4	11.3
Do	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	6.2	5.	8.
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	9.8	4.1	10.6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	3	4.4	5.5	7.
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	4	9.2	8.	12.2

Strong wind from the left.

500 *yards range.—May* 17, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	9.3	6.2	11.2
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	7.6	6.7	10.1
Service	70	Hazard, F. G.	500	.458	Frankford, like service, ice, 1-12 tin.	1	9.2	7.9	12.1
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	5.8	4.4	7.3
Service	70	....do	500	.4555	Springfield, like service, 1-12 tin.	1	7.7	4.8	9.
Service	70	....do	500	.4555	Springfield, like service, 1-12 tin.	2	8.6	3.68	9.3
18-inch twist, 3 grooves.	70	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	4.84	8.2	9.5
18-inch twist, 3 grooves.	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	7.6	8.4	11.2
18-inch twist, 3 grooves.	70	Hazard, F. G.	500	.4555	Springfield, like service, 1-16 tin.	1	7.84	3.6	8.5
18-inch twist, 3 grooves.	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	9.72	4.2	10.5
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	11.36	9.52	14.7
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	2	8.9	6.88	11.2
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	7.04	6.6	9.6
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	5.32	3.32	6.2

Stiff breeze from left and rear.

500 *yards range.—May* 17, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		Grs.						
Long-range	70	Hazard, F. G..	500	.4555	Springfield, like service, 1-12 tin.	1	9.1	6.7	11.3
Service	70	....do	500	.4555	Springfield, like service, 1-12 tin.	1	6.6	7.	9.6
Service, with lengthened chamber.	75	Dupont.......	500	.458	Frankford, like service, 1-12 tin.	1	12.8	11.1	16.9
Do.........	75	....do	500	.458	Frankford, like service, 1-12 tin.	2	8.4	7.4	11.2
						Mean..	10.6	9.2	14.
Do.........	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-12 tin.	1	3.7	4.3	5.7
Do.........	80	....do	500	.4555	Springfield, like service, 1-12 tin.	2	4.9	6.2	7.9
						Mean..	4.3	5.2	6.8
Do.........	80	Dupont.......	500	.458	Frankford, like service. 1-12 tin.	1	5.4	9.8	11.2
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	6.2	10.3	12.
						Mean..	5.8	10.	11.6
Do.........	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-12 tin.	1	8.1	5.1	9.6
Do.........	80	....do	500	.4555	Springfield, like service, 1-12 tin.	2	5.9	4.2	7.2
						Mean..	7.	4.6	8.4

Stiff breeze from the left.

500 *yards range.—May* 21, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		Grs.						
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	6.2	5.9	8.6
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	2	9.	4.8	10.2
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	3	8.2	7.2	10.9
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	4	10.1	6.9	12.2
						Mean..	8.4	6.2	10.5
Do	80	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	4.9	4.7	6.8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	10.8	7.2	13.
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	9.	5.2	10.4
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	9.4	4.4	10.4
						Mean..	8.5	5.4	10.1
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	6.4	7.7	10.
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	1	5.	7.1	8.7
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	12.1	7.6	14.3
						Mean..	8.5	7.3	11.5
Do	80	Hazard, F. G.	500	.4555	Springfield, like service, 1-12 tin.	1	5.4	6.2	8.2
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	2	4.4	4.8	6.5
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	3	6.4	6.7	9.3
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	4	4.4	5.6	7.1
						Mean..	5.1	5.8	7.8

Very strong wind from the right and rear.

500 *yards range.—May* 22, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	9.2	7.	11.6
Do	75	....do	500	.458	Frankford, like service, 1-12-tin.	2	9.8	4.5	10.8
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	3	8.3	9.4	12.5
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	4	6.	6.7	9.
						Mean	8.3	6.9	11.
Do	80	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	9.5	5.	10.7
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	10.8	8.6	13.8
						Mean	10.1	6.8	12.2
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	6.8	4.8	8.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	7.4	6.5	9.8
						Mean	7.2	5.6	9.1
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	7.9	8.5	11.6
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	7.4	5.8	9.4
						Mean	7.6	7.2	10.5

Very strong wind from the right and rear.

500 *yards range.—May* 26, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A
	Grs.		Grs.						
Service	70	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	8.1	10.8	13.5
Service	70	....do	500	.458	Frankford, like service, 1-12 tin.	2	9.2	13.9	16.7
						Mean..	8.6	12.3	15.1
Service	70	Hazard, F. G..	500	.458	Frankford, like service, 1-17 tin.	1	5.7	8.3	10.1
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	5.	6.5	8.2
						Mean..	5.3	7.4	9.1
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	3.9	3.4	5.2
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	2	4.9	6.6	8.2
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	3	4.4	6.2	7.6
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	4	5.8	5.1	7.7
						Mean..	4.7	5.3	7.2
Do	80	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	7.8	7.5	10.8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	4.5	8.8	9.9
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	8.6	7.6	11.5
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	7.9	8.5	11.6
						Mean..	7.2	8.1	10.9
Do	80	Hazard, F. G..	500	.458	Frankford, like service, 1-17 tin.	1	7.6	7.3	10.6
Do	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	6.6	6.3	9.1
						Mean..	7.1	6.8	9.8
Do	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-12 tin.	1	6.7	4.	7.8
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	2	6.1	5.4	8.1
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	3	9.8	4.3	10.7
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	4	7.7	7.2	10.5
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	5	8.	7.9	11.2
Do	80	....do	500	.4555	Springfield, like service, 1-12 tin.	6	6.5	5.4	8.5
						Mean..	7.5	5.7	9.5

Calm.

500 *yards range.—May* 28, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		Grs.						
Service with lengthened chamber.	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	5.7	7.2	9.2
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	2	2.5	5.3	5.9
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	3	6.	4.	7.2
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	4	4.9	6.1	7.8
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	5	7.5	4.4	8.7
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	6	4.5	4.6	6.4
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	7	6.4	8.2	10.4
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	8	6.8	6.4	9.3
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	9	2.5	1.9	*3.1
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	10	3.9	5.3	6.6
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	11	5.1	5.5	7.5
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	12	5.	5.4	7.4
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	13	5.6	4.1	6.9
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	14	4.5	7.3	8.6
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	15	7.	5.6	9.
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	16	5.6	4.4	7.1
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	17	5.1	5.1	7.2
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	18	6.	3.1	6.8
						Mean.	5.3	5.2	7.5

*Best recorded target at this range.

500 *yards range.—May* 31, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations.
	Grs.		Grs.						
Long-range....	80	Hazard, F. G..	500	.446	Patched, 1-19 tin........	1	4.8	8.2	9.5
Long-range....	80	....do.........	500	.446	Patched, 1-19 tin........	2	7.8	4.8	9.2
						Mean..	6.3	6.5	9.3

500 *yards range.—June* 5, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A
	Grs.		*Grs.*						
Service with lengthened chamber.	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-12 tin.	1	4.2	4.9	6.5
Do..........	80	....do..........	500	.4555	Springfield, like service, 1-12 tin.	2	5.2	6.7	8.5
Do..........	80	....do..........	500	.4555	Springfield, like service, 1-12 tin.	3	3.4	4.4	5.6
Do..........	80	....do..........	500	.4555	Springfield, like service, 1-12 tin.	4	6.7	5.1	8.4
Do..........	80	....do..........	500	.4555	Springfield, like service, 1-12 tin.	5	7.0	8.8	11.3
						Mean..	5.4	5.98	8.1
Service..........	70	....do..........	500	.4555	Springfield, like service, 1-12 tin.	1	9.0	12.8	15.6
Service..........	70	....do..........	500	.4555	Springfield, like service, 1-12 tin.	2	3.2	4.7	5.7
Service..........	70	....do..........	500	.4555	Springfield, like service, 1-12 tin.	3	6.6	10.1	12.1
Service..........	70	....do..........	500	.4555	Springfield, like service, 1-12 tin.	4	5.9	4.4	7.4
Service..........	70	....do..........	500	.4555	Springfield, like service, 1-12 tin.	5	6.7	10.0	12.0
						Mean..	6.3	8.8	10.6

Strong wind from right and rear. Frankford reloading shells were used for the 80-grain cartridges.

500 *yards range.—June* 8, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A
	Grs.		*Grs,*						
Long-range....	80	Dupont........	500	.446	Patched, 1-19 tin.........	1	4.6	5.2	7.0
Long-range....	80	....do..........	500	.446	Patched, 1-19 tin.........	2	8.16	5.04	9,59
Long-range....	80	....do..........	590	.446	Patched, 1-19 tin.........	3	5.9	3.9	7.1
Long-range....	80	....do..........	500	.446	Patched, 1-19 tin.........	4	5.5	8.2	9.9
Long-range....	80	....do..........	500	.446	Patched, 1-19 tin.........	5	5.14	7.76	9.31
						Mean..	5.86	6.02	8.58
Long-range....	80	Oriental........	500	.446	Patched, 1-19 tin.........	1	3.8	6.5	7.5
Long-range....	80	....do..........	500	.446	Patched, 1-19 tin.........	2	5.9	3.7	7.0
Long-range...	80	....do..........	500	.446	Patched, 1-19 tin.........	3	8.5	8.24	11.8
Long-range....	80	....do..........	500	.446	Patched, 1-19 tin.........	4	5.8	11.4	12.8
						Mean..	6.	7.46	9.8

Light breeze from left and front.

500 *yards range.—June* 11, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Long-range	80	Dupont	500	.446	Patched, 1-19 tin	1	7.6	4.4	8.8
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	4.8	5.7	7.5
Long-range	80	....do	500	.446	Patched, 1-19 tin	3	11.4	8.1	14.
Long-range	80	....do	500	.446	Patched, 1-19 tin	4	5.5	6.	8.1
						Mean..	7.3	6.5	9.6
Long-range	80	Oriental	500	.446	Patched, 1-19 tin	1	3.6	6.9	7.8
Long-range	80	....do	500	.446	Patched, 1-19 tin	2	3.8	5.5	6.7
Long-range	80	....do	500	.446	Patched, 1-19 tin	3	9.	8.6	12.4
Long-range	80	....do	500	.446	Patched, 1-19 tin	4	4.1	4.7	6.3
Long-range	80	....do	500	.446	Patched, 1-19 tin	5	3.6	6.1	7.1
Long-range	80	....do	500	.446	Patched, 1-19 tin	6	7.1	6.4	9.6
						Mean..	5.2	6.4	8.3

Strong breeze from the right and rear.

500 *yards range.—June* 12, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	6.6	4.4	7.9
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	7.1	5.	8.7
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	3	3.9	5.	6.4
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	4	6.1	7.9	10.
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	5	9.8	7.3	12.2
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	6	8.8	6.3	10.8
						Mean..	7.5	6.	9.3
Service, with lengthened chamber.	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	5.1	7.6	9.2
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	4.9	5.2	7.1
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	3	4.9	5.6	7.4
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	4	8.4	7.2	11.1
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	5	5.6	4.3	7.1
Do	80	....do	500	.4555	Springfield, like service, 1 16 tin.	6	7.8	6.	9.8
Do	80	....do	500	.4555	Springfield. like service, 1-16 tin.	7	6.5	5.4	8.5
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	8	6.5	6.6	9.3
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	9	3.7	6.4	7.4
						Mean..	5.9	6.3	8.5

Stiff breeze from the right and rear.

500 *yards range.—June* 14, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	5.9	7.8	9.8
Do.........	80	....do........	500	.4555	Springfield, like service, 1-16 tin.	2	5.4	6.	8.1
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	3	5.8	5.5	8.0
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	4	3.6	4.2	5.5
						Mean..	5.2	5.9	7.8

Stiff breeze from right and rear.

500 *yards range.—June* 15, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		*Grs.*						
18-inch twist, 6 grooves, with lengthened chamber.	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	5.	5.2	7.2
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	2	8.7	5.6	10.3
Do........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	3	5.5	4.4	7.1
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	4	3.4	7.3	8.0
Do.........	80	... do.........	500	.4555	Springfield, like service, 1-16 tin.	5	5.8	6.2	8.5
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	6	6.3	2.5	6.8
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	7	7.4	6.7	10.0
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	8	4.7	4.5	6.5
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	9	5.8	5.4	7.9
Do.........	80	....do.........	500	.4555	Springfield, like service, 1-16 tin.	10	5.3	5.4	7.6
						Mean..	5.8	5.3	8.0
Do.........	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	5.	9.5	10.7
Do.........	80	....do.........	500	.458	Frankford, like service, 1-12 tin.	2	6.1	12.1	13.6
						Mean..	5.5	10.8	12.1

First five targets, fresh breeze from the front; the rest calm.

500 *yards range.—June* 19, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	7.1	5.8	9.2
Service, with lengthened chamber.	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	6.1	9.8	11.1
Do.........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	4.9	5.9	7.9
Do.........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	3	6.1	8.	10.1
Do.........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	4.	5.7	5.3	7.8
Do.........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	5	4.	2.9	4.9
						Mean..	5.4	6.4	8.4

Calm.

300 *yards range.—December* 2, 5, 24, 27, 29, 1879.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
December 2.	*Grs.*		*Grs.*						
Service	70	Hazard, F. G.	500	.458	Used at Sandy Hook, full at point, 1-12 tin.	1	2.7	5.1	5.8
18-inch twist, 3 grooves.	70	....do	500	.458	Used at Sandy Hook, full at point, 1-12 tin.	1	2.6	4.4	5.1
18-inch twist, 6 grooves.	70	....do	500	.458	Used at Sandy Hook, full at point, 1-12 tin,	1	3.2	2.5	4.1
December 5.									
Service	70	Hazard, F. G.	500	.458	Shoulder front of shell, 1-12 tin.	1	3.9	3.7	5.4
18-inch twist, 3 grooves.	70	....do	500	.458	Shoulder front of shell, 1-12 tin.	1	2.7	6.8	7.3
18-inch twist, 6 grooves.	70	....do	500	.458	Shoulder front of shell, 1-12 tin.	1	3.5	7.6	8.4
December 24.									
Service	70	Service	405	.458	Service, 1-16 tin	1	3.2	2.5	4.06
Service	70	Hazard, F. G.	490	.458	Like service, 1-12 tin	1	2.5	2.1	3.26
18-inch twist, 3 grooves.	70	....do	490	.458	Like service, 1-12 tin	1	0.88	2.3	2.46
18-inch twist, 6 grooves.	70	...do	490	.458	Like service, 1-12 tin	1	3.02	3.36	4.52
Service	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	13.	5.7	14.2
18-inch twist, 3 grooves.	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	3.93	3.6	5.33
18-inch twist, 6 grooves.	70	....do	500	.45	Flat base; flat point, 1-12 tin.	1	5.8	12.7	14.
Long-range	80	....do	500	.446	Patched, 1-19 tin	1	1.96	1.6	2.53
December 27.									
Service	70	Hazard, F. G.	500	.45	Flat base; flat point, 1-16 tin,	*1	17.3	16.6	24.
18-inch twist, 3 grooves.	70	....do	500	.45	Flat base; flat point, 1-16 tin.	†1	3.3	5.3	6.2
Service	70	....do	500	.456	Flat base; flat point, 1-16 tin.	1	3.76	3.6	5.2
18-inch twist, 3 grooves.	70	....do	500	.456	Flat base; flat point, 1-16 tin.	1	6.3	5.8	8.56
18-inch twist, 6 grooves.	70	....do	500	.456	Flat base; flat point, 1-16 tin.	1	3.16	2.8	4.22
December 29.									
Service	70	Hazard, F. G.	490	.456	Flat base; flat point, 1-12 tin.	1	4.4	3.8	5.81

* Three shots missed target. † One shot missed target.

300 *yards range.—May* 3, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	3.3	3.4	4.8
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	3.	2.3	3.8
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	5.	3.9	6.3
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	2.7	3.8	4.7
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	2.2	1.9	2.9
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	2.8	3.3	4.3
						Mean	3.2	3.1	3.6
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	4.7	4.4	6.4
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	2.9	4.6	5.4
Do	80	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	6.3	4.3	7.6
Do	80	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	4.2	3.5	5.5
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	3.2	3.3	4.6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	2.3	4.9	5.4
						Mean	3.9	4.2	5.

Strong wind from left and rear.

300 *yards range.—May* 8, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	5.7	8.	9.8
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-12 tin.	1	2.7	2.3	3.5
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	3.8	2.5	4.5
Service	70	Hazard, F. G.	500	.458	Frankford, like service, 1-17 tin.	1	3.5	3.	4.6
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	3.2	2.4	4.

Light breeze from right and rear.

300 *yards range.—May* 10, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service	70	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	2.6	2.6	3.7
Service	70	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	3.	3.1	4.3
Service	70	...do	500	.458	Frankford, like service, 1-12 tin.	2	2.9	3.6	4.6
Service	70	Oriental	500	.458	Frankford, like service, 1-17 tin.	1	3.7	2.6	4.5
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	2.5	4.6	5.2
Service	70	Hazard, F. G..	500	.458	Frankford, like service, 1-17 tin.	1	3.1	5.5	6.3
Service	70	....do	500	.458	Frankford, like service, 1-17 tin.	2	2.5	4.5	5.1
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	1	2.5	2.2	3.3
Service	70	....do	500	.4555	Springfield, like service, 1-16 tin.	2	2.4	3.5	4.2
Service, with lengthened chamber.	80	Oriental	500	.458	Frankford, like service, 1-12 tin.	1	3.	5.	5.8
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	4.3	4.4	6.1
Do.........	80	Hazard, F. G..	500	.458	Frankford, like service, 1-17 tin.	1	2.2	4.3	4.8
Do.........	80	....do	500	.458	Frankford, like service, 1-17 tin.	2	2.8	2.5	3.8
Do.........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	1	3.4	2.9	4.5
Do.........	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	3.4	2.1	4.

The first nine targets, strong breeze from right and rear; the last six targets, very strong wind.

300 *yards range.— May* 22, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	4.1	2.1	4.6
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin	1	3.	4.8	5.7
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	4.7	5.	6.9
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	4.6	4.1	6.2
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	4.8	6.	7.7
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	5	5.5	3.4	6.5
						Mean.	4.5	4.7	6.6
Do.........	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	4.3	4.2	6.
Do.........	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	3.7	5.3	6.5
						Mean.	4.	4.7	6.2

Very strong wind from the right and rear.

300 *yards range.—May* 25, 1880.

Rifle.	Powder.		Bullet.			No. of target.	Deviations.		
	Weight.	Kind.	Weight.	Caliber.	Kind.		M. H.	M. V.	M. A.
	Grs.		*Grs.*						
Service, with lengthened chamber.	75	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	2.1	3.9	4.4
Do	75	....do	500	.458	Frankford, like service, 1-12 tin.	2	2.6	4.8	5.5
						Mean.	2.3	4.3	5.
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	1	2.9	2.4	3.8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	3.4	3.4	4.8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	4.2	3.8	5.7
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	3.5	5.1	6.2
						Mean.	3.5	3.7	5.1
Do	80	Hazard, F. G..	500	.458	Frankford, like service, 1-12 tin.	1	3.3	3.2	4.6
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	3.8	5.	6.3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	2.6	2.7	3.7
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	2.7	5.3	5.9
						Mean.	3.1	4.5	5.1

Calm.

300 *yards range.—June* 15, 1880.

Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		Grs.						
18-inch twist, 6 grooves, with lengthened chamber.	80	Hazard, F. G..	500	.4555	Springfield, like service, 1-16 tin.	1	4.	5. 4	6. 7
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	2	3. 6	2. 8	4. 6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	3	3. 4	2. 3	4. 1
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	4	3. 5	2.	4. 0
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	5	5. 3	4. 2	6. 8
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	6	4. 2	1. 9	4. 6
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	7	2. 5	4. 1	4. 8
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	8	3. 8	4.	5. 5
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	9	2. 9	4. 7	5. 5
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	10	2. 2	4. 3	4. 8
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	11	2. 3	2. 2	3. 2
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	12	4. 6	1. 6	4. 9
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	13	3. 8	2. 8	4. 7
Do	80	....do	500	.4555	Springfield, like service, 1-16 tin.	14	3. 8	3. 1	4. 9
						Mean..	3. 6	3. 2	4. 9
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	1	2. 1	2. 6	3. 3
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	1. 7	3. 8	4. 2
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	3	3. 7	3. 1	4. 8
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	4	2. 8	2. 6	3. 8
						Mean..	2. 6	3. 0	4. 0
Do	80	Dupont	500	.458	Frankford, like service, 1-12 tin.	1	3. 1	5. 1	6.
Do	80	....do	500	.458	Frankford, like service, 1-12 tin.	2	3.	4. 4	5. 3
						Mean..	3. 0	4. 7	5. 6

Fresh breeze from the front.

300 *yards range.—June* 18, 1880.

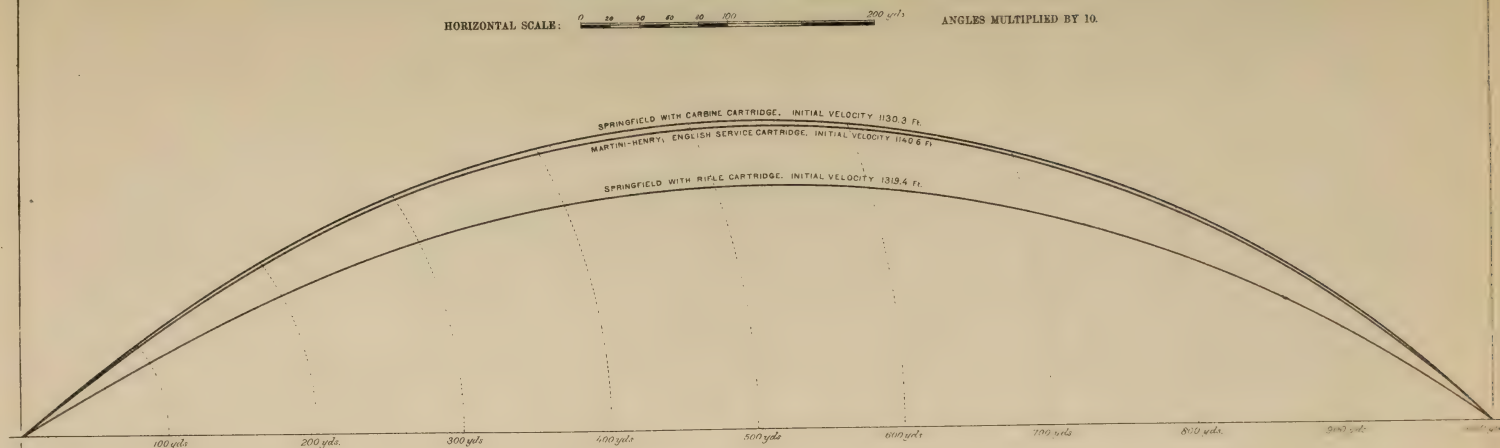
Rifle.	Powder. Weight.	Powder. Kind.	Bullet. Weight.	Bullet. Caliber.	Bullet. Kind.	No. of target.	Deviations. M. H.	Deviations. M. V.	Deviations. M. A.
	Grs.		Grs.						
Long-range	80	Hazard, F. G..	550	.446	Patched, 1-19 tin	1	2. 8	3. 4	4. 4
Long-range	80	....do	550	.446	Patched, 1-19 tin	2	1. 7	2. 2	2. 8
Long-range	80	....do	550	.446	Patched, 1-19 tin	3	1. 5	3 1	3. 5
Long-range	80	....do	550	.446	Patched, 1-19 tin	4	5. 1	3. 9	6. 4
Long-range	80	....do	550	.446	Patched, 1-19 tin	5	2. 8	4. 8	5. 6
						Mean..	2. 8	3. 5	4. 5

Calm.

TRAJECTORIES OF SPRINGFIELD AND MARTI-HENRY CARBINES,

CALIBER 0".45.

Projected by the system of Polar Distortion.



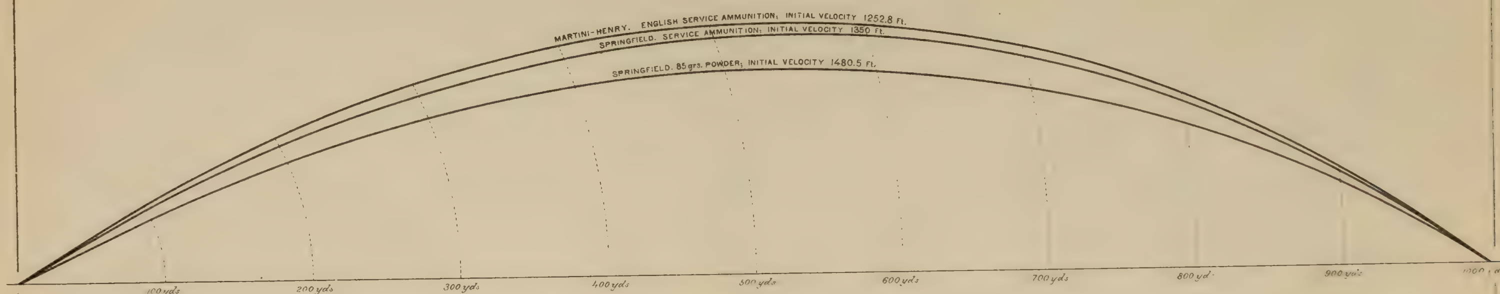
Angles of elevation computed, initial velocities, instrumentally determined, alone being known

TRAJECTORIES OF SPRINGFIELD AND MARTI-HENRY RIFLES,

CALIBER 0".45.

Projected by the system of Polar Distortion.

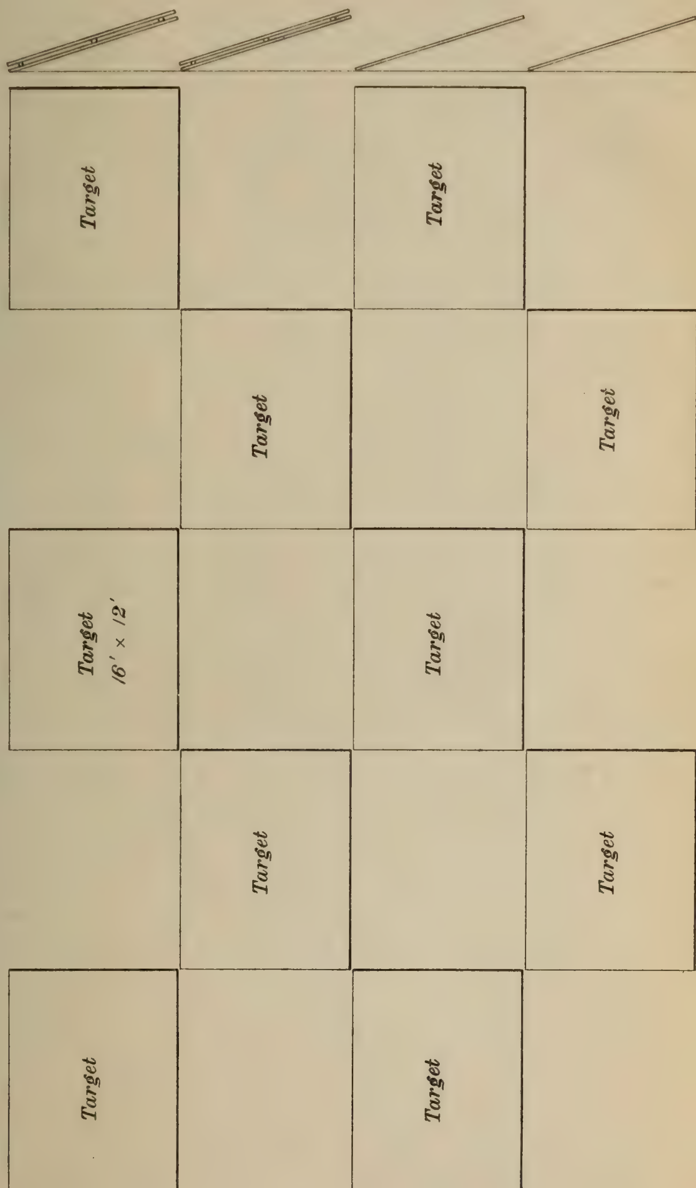
HORIZONTAL SCALE: 0 20 40 60 80 100 200 yards ANGLES MULTIPLIED BY 10.



Angles of elevation computed, initial velocities, instrumentally determined, alone being known.

ARRANGEMENT OF TARGETS.

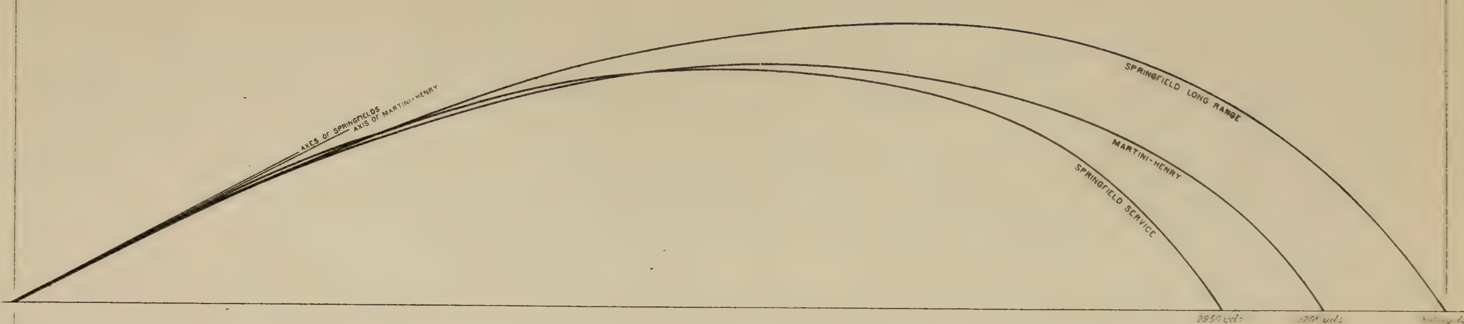
PLAN AND ELEVATION



TRAJECTORIES OF SPRINGFIELD LONG RANGE, SERVICE, AND MARTI-HENRY RIFLES,

CALIBER 0".45.

ANGLES NATURAL SIZE. SCALE: 0 50 100 200 300 400 yards



APPENDIX 26.

A SET OF TABLES AND PLATES, SHOWING PRINCIPAL DIMENSIONS AND ELEMENTS OF FIRE OF THE MOST POWERFUL RIFLED GUNS, EXISTING OR PROPOSED, AT THE COMMENCEMENT OF THE YEAR 1880; AND ALSO OF THE VARIOUS EUROPEAN RIFLED HOWITZERS AND MORTARS.

PREPARED BY CAPT. CHARLES S. SMITH, UNDER THE DIRECTION OF LIEUT. COL. S. CRISPIN, CONSTRUCTOR OF ORDNANCE.

(Fourteen plates.)

SIR: As requested by you, I have prepared, and herewith respectfully submit, a set of tables, with plates, giving the principal dimensions and elements of fire of the most powerful rifled guns, existing or proposed, at the commencement of the year 1880; and also of the various European rifled howitzers and mortars. Much of the information on rifled howitzers and mortars has already appeared in Ordnance Notes, No. 68; but it is here supplemented by the results of more recent experiments and the addition of some larger calibers, and altogether presented in a more summary shape.

The table of rifled guns has been prepared from the most reliable information available, and while it may not, in every particular, be absolutely correct, it will yet show closely enough what are the actual figures, to serve for the purpose of comparison.

To refer more particularly to this table, it will be seen that both the Italian and the English 100-ton Armstrong guns are included—the object being to show the respective powers of those two guns with regard to the particular powders employed. The Italian "progressive powder" has given excellent results, in admitting of the use of very large charges and the consequent attainment of high velocities, without subjecting the gun to any injurious pressures; at least, such was its record up to the bursting of the 100-ton gun on board the Duilio, a disaster which certain English writers have sought to attribute to the uncertain and dangerous action of the "progressive powder" rather than to a weak point in the gun itself. The Italian Government originally ordered from Armstrong's works eight of these 100-ton muzzle-loading guns for the turrets of the Duilio and Dandolo; afterwards eight more were ordered for the Italia and the Lepanto, which are to be *breech-loaders*, with the French system of fermeture.

The English 80-ton gun is the type of gun selected for the armament of the Inflexible. The four 100-ton guns purchased from Sir William Armstrong & Co. are intended for the works at Gibraltar and Malta, and were procured at a period when the exigencies of national affairs did not admit of the delay necessary for the fabrication and preliminary trial of the monster guns—160 to 200 tons—proposed by the Woolwich authorities. Since the disasters which have befallen the 38-ton gun on board the Thunderer, and the 100-ton gun on board the Duilio, the drift of opinion in England seems to be settling strongly in favor of breech-loaders; since, with such guns, the possibility of double loading could not exist, while the full exposure of the chamber after each fire would afford an opportunity for its frequent examination. It is quite possible, also, that some change of detail, if not of metal, will be made in their system of construction, since, by the creation of a chamber, the

thickness of the inner steel tube, upon which the longitudinal strain is mainly thrown, is considerably reduced, and, as would appear from the bursting of the Duilio's gun, thereby rendered too weak to support that strain.

In addition to the French guns given in the table, that government possesses breech-loading rifles of 13″.59 and 10″.63 caliber, and of 48 and 27 tons weight, respectively. There are also being constructed at Ruelle several 70-ton guns entirely of steel, of the model of 1874, the construction of which is, briefly, as follows:

The gun consists of a steel body lined with a short steel tube and banded with steel hoops, the breech-closure being the French screw. The tube is of Bessemer steel, hammered, and afterwards tempered in oil; the hoops and body of the gun are hammered puddled steel. The steel body is composed of two parts united under shrinkage, and further secured by means of a clasp. In the operation of shrinking, the forward end of the breech portion is inserted into the rear end of the chase portion, the latter being heated up for that purpose.*

The French ascribe the superiority of *all-steel* cannon to those of cast-iron hooped and tubed with steel chiefly to their greater power of penetration; though they claim their ability still to construct a cannon on the latter system (model of 1870) of equal power to the steel by increasing the caliber slightly. Thus, a cannon of the model of 1870 should have a caliber of 25 centimeters to equal a steel gun of 24 centimeters. The cost of the former would be about 23,000 francs, as against 100,000 francs for the latter; but the increase in weight, of gun and ammunition, would exceed that of the steel gun by about six tons, which is a matter of some importance on shipboard.

The Schultz wire gun has also been tested in France up to a caliber of 6″.25, and so satisfactory were the results that an 80-ton gun is now being fabricated upon that system. The wires, under the requisite degree of tension, are wrapped round a central steel tube, but are neither brazed nor welded. A steel casing is finally shrunk on over the wire-wound portion. This mode of construction is thought to give a very strong gun, as regards tangential strains, while the cost is comparatively low, owing to the inexpensiveness of the plant.

The Russian Government includes among its heavy guns the 14-inch Krupp's breech-loading rifle. A few years ago a 14-inch cast-iron rifle, hooped with steel, and having the French breech-screw, was under construction at Perm; but no accounts have been received of its trial.

The Krupp works have already determined on the model of a 125-ton gun; and since the successful trial of the 72-ton gun at Meppen last year, their ability to fabricate such a gun seems to be placed beyond question. Large numbers of heavy rifled guns of calibers below 12 inch have been furnished by these works to many of the European powers, as well as to Turkey, Egypt, Japan, and some of the South American States; and the same is true, though to a more limited extent, of the Armstrong works. The 11-inch rifles furnished by the latter to the Chinese Government are for the gun-boat service; that government has also some 38-ton Armstrong guns in the same service.

The Brazilian Government has, in its naval service, some 35-ton guns, manufactured by Whitworth, of fluid-compressed steel, and rifled upon the hexagonal principle.

The proposed American 12-inch breech-loading rifle—given in the table—while it embraces the main features of the model now definitely

* "Manuel D'Artillerie," par H. Lee Barzic, Lieut. de Vaisseau.

adopted, varies from it somewhat in details. It is shorter, for instance, by a full caliber, in length of bore, and heavier by some four or five tons. The adopted model will probably admit of a charge of 300 pounds of powder and have a total weight of about 50 tons. It should give an energy of 23,991 foot-tons at the muzzle, which would be sufficient to penetrate 44 inches of iron, or 35 inches at a distance of 1,000 yards.

The table includes certain guns of minor caliber—5″.87, 6″, 8″, and 9″.45, respectively—but of relatively great power, owing to the large charges employed.

It will be observed that these guns have a large chamber for the reception of the charge, and a commensurate length of bore for its consumption. The number of cubic inches allowed per pound of powder indicates also that there is considerable windage, or air-space, about the cartridge in the chamber. As it is chiefly due to this allowance of air-space that the employment of large charges, without overstraining the gun, has been rendered practicable, it may be interesting to examine briefly the underlying physical causes on which the effect of air-spacing depends.

I. The tension of an elastic fluid, supposing the temperature to remain constant, varies directly as the density, and the density varies inversely as the volume or space occupied. The precise laws* according to which these variations take place in the bore of a gun may not be absolutely determined; but it is enough for our present purpose to know that the greater the density of the gunpowder gas the higher will be its tension; and the more contracted the space in which a given charge is burned, or the larger the charge burned in a given space, the greater will be the density of the resulting gas. Hence, powder burned in its own volume should yield its maximum effect; and that this is the case is fully sustained by experiment.

In the above statement lies the fundamental principle involved in air-spacing.

II. The velocity of inflammation, or the rate at which the ignition is spread from one grain of a charge of powder to another, depends—other things being equal, as size, shape, and density of grain, diameter of cartridge, &c.—on the greater or less confinement under which the charge is fired; that is, it depends on the degree of *tension* of the gas in the first instants of explosion. As the tension is higher, so will the inflamed gas be propelled the more forcibly through the interstices of the charge, and consequently the more rapid the spread of the ignition. That this is so will appear from the following results of actual experiment.†

Trains of service powder, containing about 0.11 pound of powder to the linear foot, were fired under different conditions as to confinement.

	Velocity of inflammation.
On a plane surface in the open air	7.87 feet.
In an uncovered trough	8.13 "
In a linen tube	11.38 "
In the same tube placed in a trough	17.48 "
In the trough covered up	27.88 "

These velocities are considered less than those obtained in fire-arms for the reason that, in the latter, the powder is not only confined at the sides but at one end, which was not the case in the covered trough,

* Analysis and experiment alike prove that the *pressure* increases more rapidly than the density.

† Benton's Ordnance and Gunnery, pages 51–52.

where the gas could expand in both directions.* A velocity of more than 300 feet can be obtained by burning quick-match inclosed in a cloth tube.

Experiments have also proved that the velocity increases with the sizes of cross-section of the train; that it is greater with fine-grained powder than for coarse, except where the interstices are too much reduced, as in the case, for instance, of mealed powder.

III. The velocity of combustion, or the rate of burning of each grain from its surface to its center, other things being equal, depends on the pressure or *tension* of the surrounding gas. On this point Messrs. Noble and Abel, in their report on experiments with fired gunpowder (pages 121–122), state as follows:

"Piobert's views, moreover, that the pressure exerts but a trifling influence upon the rate of combustion, appears to us entirely untenable. With a particular sample of service pebble-powder, we found the time required for burning a single pebble in the open air to be about two seconds. The same sample was entirely consumed in the bore of a 10″ gun, and must, therefore, have been burned in less than .009 of a second."

The fact has also been clearly established by recent experiments made in France, in which mealed powder was driven into a steel tube closed at one end, and then burned under a smaller and smaller orifice for the escape of the gas. Care was taken in filling the tube to have the column of powder of a constant length and density. These experiments proved that an augmentation of pressure was always accompanied by an increase in the velocity of combustion, and that this result was apparent for the most feeble increments of pressure. †

When we consider that a grain of powder is a substance more or less heterogeneous and porous, it should seem to follow, as a necessary result, that under great pressure the highly inflamed gases would be forced into the softer parts and interstices of the grain itself, and the velocity of combustion thereby enormously increased. That the combustion of the grains does not proceed in parallel layers from the surface to the center is sufficiently evident from the appearance of half-burned grains which have been picked up after discharge.

Now, bearing in mind the above considerations, it will be readily seen that in the burning of a charge of powder where a certain air-space or windage about the cartridge is allowed, we obtain to a greater or less degree, depending upon the amount of that air-space, the conditions essential to a slow, deliberate gasification of the charge. The portion of bore allotted to the charge being larger than where no windage is allowed, the tension of the gas first formed will be lower, and inflammation and combustion will proceed more slowly. As a consequence of this slower evolution of the gas, the inertia of the projectile will be more gradually overcome and the strain upon the gun will be less. The *maximum* tension also of the gas, owing to the larger space afforded for its expansion, and its consequently lower maximum density, will be less, and both the velocity of the projectile and the pressure per square inch on the bore of the gun will be diminished. The operation is analogous indeed to that which obtains by the employment of the larger grained and denser powders.

* Benton's Ordnance and Gunnery, pages 51–52.

† Sarrau assumes that the velocity of combustion is proportional to a positive power of the pressure; but since it increases less rapidly than the pressure, the exponent of that power must be less than unity.

As an illustration of the effect of air-spacing in thus reducing the velocity and pressure, the following results, extracted from the published record of recent experiments with a 38-ton gun at Woolwich, are presented:

No. of round.	Air-space, feet.	Charge pebble powder, lbs.	Shell and weight, lbs.	Velocity, feet.	Pressure, tons per square inch.
2	....	110	Palliser, 703	1,408	21.8
4	1	110	Palliser, 703	1,311	15.2
6	2	110	Palliser, 697¾	1,223	12.7
8	4	110	Palliser, 705	1,013	12.6
10	6	110	Palliser, 705	876	8.9
12	8	110	Palliser, 701	754	7.4
13	10	110	Palliser, 698	582	6.1

Here the air-space consisted in leaving, successively, an interval between the cartridge and the projectile of 0, 1, 2, 4, &c., feet.

Now, the practical application of these facts lies obviously in adding to the charge, and in that way increasing the velocity, until the latter reaches to the highest attainable point for the length of bore or powder-burning capacity of the gun; since we can at the same time keep down the pressure within safe limits by the due allowance of air-space. The length of the cartridge, however, must not be overlooked, for if that is too great relatively to the diameter, there will be a likelihood of the occurrence of those extremely dangerous tensions known as "wave pressures." The shorter and fuller the charge also, the more favorable is its state for total consumption in the gun. With most of the existing cannon, owing to their very limited length of bore, it is not possible to realize more than partially the vast increase of power thus attainable by means of air-spacing. Hence the necessity for new constructions, involving as their prominent features great length of bore and a suitably proportioned powder-chamber. For an assumed length of bore, the largest charge that can be usefully employed is determined from the number of the "volumes of expansion"—as English artillerists term them—the bore can contain; that is, the number of times that the volume of the bore can contain the volume of the charge. The lowest limit of this ratio, or the point below which no increase of the charge will sensibly augment the velocity, is, of course, first ascertained from actual experiment. So likewise for a given charge the appropriate length of bore must be determined from a consideration of this same ratio.

To complete our view of the subject, let us trace briefly the probable mode of action of the explosive or propelling force in the ordinary and in the chambered gun. In the first case, the various phenomena of explosion of the charge occur in a relatively short period of time; the resulting tension of the gas is high, and the projectile is subjected to an impulse sudden and violent, but which is soon exhausted from the relatively small weight of charge employed and the greatly increased space soon left by the movement of the projectile for the expansion of the gas. Hence we obtain, perhaps, the maximum effect per pound of powder, but also a relatively high strain upon the gun. In the second case, we obtain, with the air-space and a much larger charge, at first a slower, and then a more uniform and prolonged pressure upon the projectile. Motion is acquired more gradually, and, owing to the large volume of the gas and the great length of the bore, the projectile is

subjected to a longer-continued action of the propelling force. We thus obtain ultimately a much higher velocity, but from the comparatively low tension of the gas no greater pressure on the walls of the piece than in the case of the unchambered gun.

Captain Noble and Mr. Abel, in the report already alluded to, thus describe the operation of discharge in the ordinary case.

"The charge of powder is not instantly exploded, but is generally ignited at a single point; the pressure (commencing at zero) goes on increasing at an extremely rapid rate until the maximum increment is reached. It still goes on increasing, but at a rate becoming gradually slower, until the maximum tension is reached, when the increase of density of the gas, aided by the combustion of the powder, is just counter-balanced by the decrease of density due to the motion of the projectile. After the maximum of tension is reached, the pressure decreases, at first rapidly, subsequently slower and slower." *

The more gradual action, then, of the propelling force, which, in the ordinary case, occurs only at an advanced stage of the combustion of the charge, and after the projectile has begun to move from its place, takes place from the outset where a suitable air-space is allowed.

Captain Rodman determined, from some experiments made in 1859, in which he employed cast-iron shells of different interior capacities, filled with one-fourth the weight of powder they had previously been found to contain, that "where the volume of powder bears a constant ratio to the space in which it is burned the pressure will be sensibly uniform." †

This conclusion, however, which is only a reasonable inference from Mariotte's law, will hardly apply without some qualification to the altered conditions of discharge in the bore of a gun, where the powder-gases seldom reach their extreme tension, owing to the enlarged space afforded for their expansion by the displacement of the projectile. And as this displacement occurs the more readily, accordingly as the weight of the projectile ‡ is less in proportion to the area subjected to the action of the propelling force, we should expect, other things being equal, a higher tension of the gases, and therefore a greater pressure on the walls of the bore, as the caliber of the piece is enlarged. Hence the employment of coarser grained and denser powders, or, which is to the same effect, more allowance of air-space in the larger calibers.§

The control which, as we have seen, we thus obtain over the burning of gunpowder by means of air-spacing, opens a new field for investigation and progress in artillery. Already there is a tendency abroad to desist from the production of monster guns, and to employ instead guns of smaller caliber, but chambered for very large charges. Of course the latter feature necessitates a considerable increase in the length of

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*If these variations in pressure be represented by a curve, it would commence at the origin convex to the axis of x, would then become concave, then again convex, and would finally be asymptotic to the axis of x.

In the same way the curve, representing the velocity, would commence by being convex to the axis of abscissæ; it would then become concave, and, were the bore long enough, would be finally asymptotic to a line parallel to the axis of x.—(Researches on Explosives: Fired Gunpowder. By Captain Noble and Professor Abel.)

†The same relation is expressed by the formula of Count Rumford, also deduced from the observed pressures in a close vessel.

‡For similar projectiles, the area subjected to pressure increases as the square, while the weight—the resistance to be overcome—increases as the cube of the caliber.

§So, too, for an increase of *charge* with the same caliber, the same proportional displacement of the projectile not occurring at so early an epoch there results an increase of tension.

the bore; a length of from 25 to 30 calibers not being deemed excessive where the weight of the charge equals one-half that of the shot. The great length thus entailed on the gun may, in some respects, prove a source of inconvenience. Another objection, suggested in connection with the high velocities attained and the comparatively light weight of the gun itself, is the severity of the recoil. This objection, however, is not insurmountable.

It has long been known that, by reducing the diameter of the cartridge, the strain on the gun might be diminished; but it does not appear that this knowledge was ever utilized for increasing the charge, and thus for adding to the velocity. As early as 1833 Captain Piobert, of the French artillery, proposed increasing the space in rear of the ball by diminishing the diameter of the cartridge, or by interposing an elastic wad between the powder and ball, in order to prevent the very rapid destruction of brass siege-guns, which is caused by the use of large charges.

Captain Mordecai, in his report of "Experiments on gunpowder," 1842–'45, states in his conclusions: "For the purpose of diminishing the strain on the gun, I propose that the principle of increasing the length of the cartridge, by reducing the diameter, should be adopted for heavy guns."

In referring also to the results of experiments made by a board of French officers at Metz, in 1836–'37, on reducing the diameter of the cartridge, he states: "Although the range of my experiments did not allow me to verify these results, I have permitted myself to make the foregoing remarks on the French experiments in order to call the attention of the Ordnance Department to a matter which may be of the greatest importance to us, in reference to giving increased durability to our iron guns, and diminishing the risk of accidents which have been lately of frequent occurrence from the bursting of these guns."

Captain Rodman also, in 1857–'58, made a series of experiments to determine "the effect of windage in the cartridge upon the pressure exerted by equal charges." His results confirmed those obtained by earlier experimenters.

It was not, however, until a very recent day that experiments is this direction took such shape as to result, finally, in the true application of this important principle, namely, in increasing largely the powder-charge.

During the experiments with the 80-ton gun in England in 1876–'77, when every effort was being made to increase the power without compromising the safety of that piece, the attention of the English authorities was directed to certain experiments being made in Germany with an increased air-space over the cartridge, by means of which larger charges were employed, with the attainment of higher velocities, and yet with moderate pressures.

Shortly after, the Armstrong 6-inch, and 8-inch, and the Krupp 5-inch and 9.45-inch chambered guns were produced, burning the enormous charges of one-half the weight of their projectiles, and with the attainment of the astonishing velocity of 2,100 feet—astonishing from the fact of the very moderate pressure accompanying it.

In connection with this subject of air-spacing, attention is called to a conclusion drawn from experiment by both Captains Mordecai and Rodman, which does not harmonize, wholly, with the foregoing deductions.

Captain Mordecai states that it appears from the results of his experiments, made with cartridges of different diameters and lengths, "That whilst the usual diameter of the cartridge for the 24-pounder gun as

now established (5″.35) is favorable to the development of the force of the charge, no great diminution of effect arises from reducing the diameter to 5 inches; on the other hand, *the force of the charge is vastly reduced by increasing the diameter of the cartridge to the full size of the bore.*"

He then proceeds to account for the latter result (pp. 288–289, "Experiments on Gunpowder"). Captain Rodman states (p. 179, "Experiments on Metals for Cannon") in regard to the results obtained in his experiments on the effect of windage in the cartridge, in a 42-pounder S. B. gun, "These results, both pressures and recoils, indicate that *the pressure increases with the windage up to about one inch windage*, beyond which the pressures and recoils both gradually diminish as the windage in the cartridge increases."

This apparent anomaly will admit, perhaps, of explanation by reference to those principles we have had under consideration. To quote Captain Rodman's own words—used in another connection—"from the fact that there was no vacant space around the cartridge, all the powder that was burned before the shot moved must have been burned in its own volume, and the maximum pressure would be reached before the charge would be nearly consumed;" the force of the gas would thus be sufficient to roll forward the spherical shot, offering, as it does, but little resistance to motion, at an earlier epoch of the combustion than is usual, and the equivalent to an air-space be produced of greater extent probably than results with the employment of the service cartridge; hence a falling off in velocity and pressure.

It was not believed that such results would obtain in the case of a rifle-projectile, which offers a much greater resistance to motion; the following series of experiments, therefore, were undertaken at the Proving Ground, Sandy Hook, N. J., for the purpose of determining this point.

(1.) The gun employed was an 8-inch rifle, vented in the prolongation of the axis of the bore.

The record of firing was as follows:

No. of rounds.	Charge.		Weight of shot.	Windage over cartridge.	Mean.	
	Kind of powder.	Weight.			Velocity.	Pressure.
		Pounds.	*Pounds.*		*Feet.*	*Pounds.*
1	Hexagonal, E. V. J.; density 1.75; grain, 72.	*35	180	Service windage about $\frac{1}{10}$ of the diameter of the bore.	1,382	30,500
2		30	180	Service windage.	1,258	20,000
2		30	180	Service windage reduced 50 per cent.	1,263	23,000
2		30	180	None.	1,344	25,500

*Service battering charge.

Gain, due to entire suppression of windage, in { Velocity, 86 feet. Pressure, 5,500 pounds.

(2.) Gun employed, 3-inch breech-loading rifle, vented on top. The record of firing was as follows:

No. of rounds.	Kind of powder.	Weight of charge.		Weight of shot.	Windage over cartridge.	Mean.	
		Pounds.	Ounces.			Velocity.	Pressure.
				Pounds.		*Feet.*	*Pounds.*
2	J. K.; grain, 2,200; density 1,725.	2	....	$12\frac{1}{4}$	$\frac{1}{10}$ of the diameter of the bore.	1,269	20,250
2		2	....	$12\frac{1}{4}$	None	1,318	24,750

Gain, due to entire suppression of windage, in $\begin{cases} \text{Velocity, 49 feet.} \\ \text{Pressure, 4,500 pounds.} \end{cases}$

These results, taken in connection with the others that have been given, would seem to establish, conclusively, the fact of the uniformity of operation of the laws involved in air-spacing; while at the same time they serve to explain the apparent exception.

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I.—TABLE SHOWING THE WEIGHTS, DIMENSIONS, CHARGES, ETC., OF THE MOST POWERFUL SERVICE AND EXPERIMENTAL GUNS EXISTING OR PROPOSED AT THE COMMENCEMENT OF 1880.

Nature of gun	Caliber.	Weight	Total length.	Length of bore.		Twist in number of calibers.	Number of grooves.	Powder-chamber.				Powder-charge.		Projectile.			Ratio of weight.		Initial velocity.	Pressure per square inch of bore.	Muzzle energy.				(Calculated.)* Penetration in iron.		Remarks.
								Length.	Diameter.	Cubic inches of air-space per lb. of powder.	Density of loading.	Weight.	Nature of powder.	Length.	Weight	Means of rotation.	Of charge to weight of projectile.	Of projectile to weight of piece.			Total.	Per square inch of shot's cross section.	Per pound of powder.	Per pound of weight of gun.	At muzzle.	At 1,000 yards.	
	Inches.	Tons.	Feet.	Feet.	Calibers			Inches.	Inches.			Lbs.		Calibers	Lbs.				Feet.	Tons.	Foot-tons.	Foot-tons.	Foot-tons.	Foot-lbs.	Inches.	Inches.	
ENGLISH.																											
Woolwich.																											
M. L. cannon of coiled wrought-iron, lined with tube of cast-steel. Frazier's system.	16.	80.	26.9	24.	18.	Increasing from 0 to 1 in 35.	11	Not enlarged.		34.	.816	370.	W. A.: P², cubes 1½-inch edge.	2.5	1,700	Bronze studs and expanding gas-check.	4.6	105.	1,520	20.5	27,237	135.35	73.60	340.4	28.62	22.13	The number of grooves definitely decided on for the 80-ton gun is 32, and the rotation will be given by means of the expanding gas-check, the studs being dispensed with.
								59.6	18.	34.	.816	425.	W. A. exptl.	2.5	1,760		4.1	101.	1,584	21.	30,612	152.25	72.02	383.3	32.17	28.08	
								59.6	18.	31.5	.880	460.	W. A., prismatic.	2.5	1,760		3.8	101.	1,626	19.5	32,257	160.43	70.12	403.6	33.90	29.19	
	12.5	38.	18.75	16.5	15.84		9	Not enlarged.		25.	1.109	130.	W. A.: P², cubes 1½-inch edge.	2.5	800	Bronze studs.	6.	106.	1,451	23.	11,676	95.14	89.81	307.3	20.10	16.84	
								40.12	14.	30.	.924	200.		2.5	800	Bronze studs.	4.3	99.	1,590	21.	14,023	114.28	70.11	368.7	24.14	19.97	
B. L. cannon of coiled wrought-iron, lined with tube of cast-steel. Proposed model.	12.	42.	27.75	26.	26.	....	.....	58.35	15.5	35.5	.781	285.	....	2.5	700	Copper bands.	2.8	134.	2,002	....	19,449	171.97	68.24	463.07	36.33	28.21	The weight of this gun will probably be increased to upwards of 60 tons.
Elswick.																											
M. L. cannon of coiled wrought iron, lined with tube of cast-steel. Armstrong's system.	17.72	100.	32.9	30.25	20.	1 in 150 to 1 in 50 at 2".88 from muzzle, remainder uniform.	28	55.12	19.7	36.	.770	463.	Pebble, 1½ inch.	....	2,010	Expanding gas-check.	....	....	1,640	21.	37,476	151.97	80.94	374.8	32.11	25.88	The length of chamber of this gun is practically 59.7 inches.
M. L. cannon of coiled wrought-iron, lined with tube of cast-steel. Armstrong's system.	8.	11.45	18.21	17.37	26.	From 1 in 85 to 1 in 40.	17	38.3	10.5	36.9	.751	85.	Pellet, d. = 1.786.	2.5	182	Expanding gas-check.	2.14	195.	1,930	13.15	4,700	93.50	55.29	401.5	19.75	13.22	With the 8-inch Armstrong chambered B. L. gun, with a charge of 105 pounds and projectile of 80 pounds, a velocity of 2,976 feet has recently been obtained.
										34.8	.789	90.			182		2.02		2,030	15.4	5,199	103.41	57.75	454.1	21.85	14.35	
										33.0	.840	95.			182		1.90		2,100	17.05	5,564	110.69	58.56	485.9	23.39	15.15	
M. L. cannon of coiled wrought-iron, lined with tube of cast steel. Armstrong's system.	6.	3.9	12.	11.5	23.	From 1 in 91 to 1 in 38.	16	22.14	8.08	31.1	.877	33.	Pellet, d. 1.820.	2.5	69.9	...do	2.11	125.	1,962	13.4	1,863	60.09	56.45	480.0	13.92	7.86	
										30.2	.918	34.		2.5	69.7	...do	2.		2,003	14.6	1,937	62.48	56.97	496.7	14.47	8.07	
GERMAN.																											
Essen.																											
B. L. cannon steel-hooped. Krupp's system............	15.75	71.	32.8	28.57	21.77	1 in 45.	90	61.5	17.32	32.77	.846	440.	Prismatic, d. 1.75 with 1 hole.	2.8	1,709	Copper bands.	3.8	93.	1,622	19.7	31,168	160.00	70.84	439.0	33.80	29.06	
										29.8	.932	484.		2.8	1,711	Copper bands.	3.5	93.	1,702	20.9	34,359	176.4	70.99	484.	37.26	31.81	
	13.976	51.	29.13	25.38	21.8	1 in 45.	80	42.68	14.37	27.35	1.014	253.	....do	2.8	1,155	Copper bands.	4.5	99.	1,642	22.	21,587	140.72	85.32	423.3	29.73	24.97	
	12.	38.	25.09	22.	22.	1 in 55.	68	37.12	12.24	27.57	1.015	158.4	Prismatic.	2.8	733	Copper bands.	4.6	116.	1,649	....	13,817	122.17	87.10	363.6	25.81	21.09	
	12.	36.	22.	18.91	18.91	1 in 72.	72	41.8	12.4	38.	.730	132.	Prismatic, 1 inch deep, d. = 1.75.	2.8	666	Lead coating.	5.	121.	1,501	13.	10,401	91.97	78.79	285.5	19.43	15.87	
								41.8	12.4	35.	.792	143.		2.8	664	Lead coating.	4.6	121.4	1,517	19.5	10,593	93.64	74.06	294.3	19.80	16.12	
	9.45	17.67	23.41	17.75	22.5	1 in 45.	54	50.	11.26	29.	.96	171.6	Prismatic, 1 hole, d. = 1.75.	2.8	353	Copper bands.	2.05	112.	1,912	18.88	8,946	134.58	52.77	506.3	26.95	20.07	The velocities for this gun are those taken at 115 feet from the muzzle.
										28.2	.99	176.4		2.8	308	Copper bands.	1.75	129.	2,086	19.49	9,291	132.47	52.67	526.1	27.99	19.49	
	5.87	3.8	13.78	12.6	25.4	Increasing Final. 1 in 25.	36	28.	6.89	28.	.99	37.4	Prismatic, 7 holes, d. = 1.75.	2.8	68.9	Copper bands.	1.83	124.	2,135	19.	2,177	80.29	58.10	572.9	17.00	9.32	
										30.5	.91	34.1		3.5	112.2	Copper bands.	3.2	75.8	1,676	18.	2,184	80.70	64.05	574.7	17.05	12.48	
ITALIAN.																											
Turin.																											
B. L. cannon of cast-iron, hooped with steel. General Rosset's system.	18.1	87.	29.52	27.5	18.25	1 in 60.	60	......	18.6	36.5	.75	440.	Prismatic or progressive.	2.6	2,200	....	5.	90.	1,378	Probably about 14 tons.	28,959	112.55	65.82	322.86	23.78	20.87	The fabrication of this gun, it is understood, has been completed, but no reports of its trial have been received. The velocity given is the *calculated*.
	12.6	38.	22.5	21.	20.	1 in 70.	48	35.66	13.1	30.	.924	132.	Dice.	2.7	770	Copper bands.	5.8	109.	1,365	15.8	9,945	79.71	75.54	262.3	16.85	14.13	
												158.	Progressive.				4.8	109.	1,492	12.6	11,881	95.17	74.97	312.8	20.13	16.63	
Elswick.—Navy.																											
M. L. cannon, forged iron, tube of cast-steel. Armstrong's system.	17.72	100.	32.98	30.5	20.5	Increasing from 1 in 250 to 50.	27	64.8	19.75	36.	.770	550.	Progressive.	2.78	2,110	Expanding gas-check.	3.8	106.	1,686	....	41,588	168.64	60.06	415.9	35.63	30.41	One of these guns recently burst on board the Duilio by pulling apart in the breech portion under a charge similar to that given.
	17.	100.	32.98	30.5	21.7		27	—	Not enlarged.		—	375.		2.78	2,000		5.6	112.	1,542	13.	32,966	145.23	87.87	329.7	30.69	26.63	
FRENCH.																											
B. L. Cannon, steel-hooped..............	18.11	124.	33.59	31.09	20.6	....	....	....	....	....	....	575.	Wetteren, 0".6 x 0".8.	......	2,645	Copper bands.	4.6	105.	1,640	....	49,316	191.46	85.77	397.8	40.45	35.73	This gun is reported as being under fabrication.
B. L. cannon, cast-iron, hooped and lined with steel.....	12.599	38.	20.	17.	16.1	Increasing 1 in 45.	....	....	Not enlarged.		....	139.		2.5	770	Copper bands.	5.5	115.6	1,371	....	10,033	80.48	72.18	264.6	17.00	14.24	The charge is determined from the assumed velocity.
RUSSIAN.																											
B. L. cannon, cast-steel, hooped..............	12.	39.	20.	17.	17.	....	36	....	12.3	....	....	114.	Prismatic.	2.5	650	Lead coating.	5.6	135.	1,400	....	8,764	77.50	76.87	224.7	16.37	13.59	
CHINESE GOVERNMENT.																											
Elswick.																											
M. L. cannon of coiled wrought-iron, lined with tube of cast steel. Armstrong's system.	11.	35.	....	....	....							235.	Pebble.	....	525	....	2.2	149.	1,817		12,295	128.74	52.30	351.3	27.33	20.53	
UNITED STATES.																											
M. L. cannon, cast-iron, lined with coiled wrought-iron tube.	12.25	40.	21.81	18.74	18.55	1 in 70.	21	—	Not enlarged.		—	115.	Hexagonal, d. = 1.785.	....	700	Expanding gas-check.	6.	128.	1,485	15.	10,701	90.80	93.05	267.5	19.18	15.75	The fabrication of this gun will be commenced during the present year.
B. L. cannon (proposed model), lined with steel and coiled wrought-iron tube.	12.	55.	28.3	25.	25.	....	....	57.	15.5	35.	.792	290.	Hexagonal.	3 to 3.5	800		2.7	154.	1,886	....	19,726	174.42	68.02	358.82	36.85	29.83	

* By Major Maitland's formula.

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II.—TABLE OF PRINCIPAL DIMENSIONS OF EUROPEAN 6-INCH RIFLED HOWITZERS AND MORTARS.

Piece.	Material of piece.	System of mechanism.	Caliber of piece.	Weight.	Length. Nominal exterior.	Length. Of chamber.	Length. Of rifling.	Length. Total of bore.	Length. Maximum exterior.	Diameter. At muzzle.	Diameter. Over breech-band.	Diameter. Of trunnions.	Diameter. Of chamber.	Rifling. No. of grooves.	Rifling. Width of grooves.	Rifling. Width of bands.	Rifling. Depth of grooves.	Rifling. Twist.	Preponderance.	Nature of gas-check.	Carriage. Nature.	Carriage. Material.	Carriage. Weight.	Carriage. Maximum elevation allowed.
			Inches.	Pounds.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Feet.	Pounds.				Pounds.	
German 15 c. m. B. L. howitzer (Krupp's system)	Steel	Cylindro-prismatic wedge	5.9	2,530	70.87	...	...	62.36	...	...	...	...	...	18	0.87	0.17	0.059	9.87	...	Steel rings	Service siege-carriage	Wrought-iron	2,574	45°
Russian, 6-inch B. L. mortar	Bronze	Prismatic wedge	6.0	3,461	53.30	17.	22.97	39.57	17.0	15.0	...	8.75	7.0	24 (parallel.)	0.647	0.13	0.07	20.0	...	Copper ring	Top carriage and chassis or director.	Wrought-iron, with wooden director.	2,692	75°
Austrian 17 c. m. B. L. mortar	Cast-iron	Cylindro-prismatic wedge	6.57	4,486	67.16	...	31.10	...	...	...	...	...	...	30 (cuneiform.)	0.428	0.326	0.086	33.66	...	...	Wrought-iron, similar to the 8" mortar carriage	...	...	...
*French 15 c. m. B. L. mortar	Cast-iron	French screw	5.9	1,320	43.30	11.81	20.05	33.86	13.8	9.84	...	...	...	...	...	...	...	10 to 13	...	...	...	...	...	...
English, 6".3 M. L. howitzers	Wrought-iron, steel tubed.	...	6.3	2,010	54.	53.	39.7	45.0	17.25	10.0	...	5.5	...	20	0.5	0.489	0.1	from 52 to 16	...	...	40-pounder siege.	Wrought-iron	3,100	35°
Krupp, 15 c. m. B. L. mortar	Steel	Prismatic wedge	5.9	794	37.4	...	...	29.72	12.59	8.0	...	4.5	6.06	18	0.8661	0.1575	0.59	7.375	88	Steel ring	Carriage without chassis.	Wrought-iron	913	60°

* Proposed.

III.—COMPARATIVE TABLE OF FIRE OF EUROPEAN 6-INCH RIFLED HOWITZERS AND MORTARS.

Piece.	Caliber.	Weight.	Approximate length. Of bore.	Approximate length. Of rifling.	Twist of rifling. Calibers	Twist of rifling. Final inclination.	Charge. Kind.	Charge. Weight.	Projectiles. System.	Projectiles. Length.	Projectiles. Weight, loaded.	Projectiles. Bursting charge.	Ratio of— Weight of charge to weight of projectile.	Ratio of— Weight of projectile to weight of piece.	Initial velocity.	Elevation.	Pressure per square inch of bore.	Recoil.	Range.	Time of flight.	Mean deviation. Longitudinal.	Mean deviation. Lateral.	Mean deviation. In direction.	Derivation.
		Tons.	Calibers.	Calibers.				Pounds.		Calibers.	Pounds.	Pounds.			Feet.		Pounds.	Feet.	Yards.	Seconds.	Yards.	Yards.		
German 15 c. m. B. L. howitzer (Krupp's system)	5.9	1.1294	10.5	...	20	...	Grs., 0".24 to 0".40 diameter.	5.5	Copper bands	2.65	66.	...	1 to 12	1 to 38	979	45°	...	...	6,550	...	97.4	25.3	...	...
Russian, 6-inch B. L. mortar	6.0	1.5451	6.66	3.83	40	4° 29'	Cannon	7.19	Lead coated	2½	76.5 *81.	5.3 3.3	1 to 11	1 to 45	800	...	...	...	...	...	...	...	...	...
Austrian 17 c. m. B. L. mortar	6.57	2.0027	...	4.7	61	2° 55'	Stein	7.39	Lead coated	2½	84.92	6.8	1 to 11	1 to 52	...	45°	...	...	4,339	...	30.9	5.79	...	...
								4.9	Lead coated	...	84.92	6.8	...	...	...	70°	...	...	2,676	...	31.7	9.51	...	...
Belgian, 15 c. m. B. L. mortar	5.9	0.5893	5.64	3.34	20 to 26	...	...	1.76	Copper bands	2½	64.6	...	1 to 36	1 to 20	620	45°	14,250	...	2,500	...	...	...	...	...
English, 6".3 M. L. howitzer	6.3	0.8973	7.1	6.2	100 to 30	...	R. L. G.	4.	Expanding sabot	2½	69.3	7.	1 to 17	1 to 29	...	15°	...	...	3,164	...	...	...	1.32	...
								2.	Expanding sabot	...	69.3	7.	...	...	...	35°	...	...	2,801	...	...	...	1.52	...
Krupp, 15 c. m. B. L. mortar	5.9	0.3545	5.04	...	15	...	Grs., 24" to 39"	3.3	Copper bands	2¾	69.45	5.14	1 to 21	1 to 11	...	40°	...	...	3,773	...	18.6	5.8	...	...
							D = 1.64	1.98	...	2¾	69.45	5.14	1 to 35	1 to 11	...	45°	...	...	2,187	...	11.26	6.3	...	...

REMARKS.—The Russian 6" mortar was employed to test the penetration of mortar shells on an iron-plated deck, 16' x 32', placed at 1,026 yards distance. The angle of fire was 60°. The projectiles fell point foremost, and the results—as regards penetration—were good. Nothing is stated respecting the accuracy of the fire. The Austrian 6".5 mortar was considered unreliable at the time it was tested. The Belgian 6" has not been fabricated as yet; the above figures being the details proposed. The English 6".3 howitzer, as given above, is the latest model of which a large number have recently been ordered for the siege train. (*Revue D'Artillerie, July*, 1878.)
* Used for armor penetration under high angles.

IV.—TABLE OF PRINCIPAL DIMENSIONS OF EUROPEAN 8-INCH RIFLED HOWITZERS AND MORTARS.

Piece.	Material of piece.	System of breech mechanism.	Caliber of piece.	Weight.	Length. Nominal, exterior.	Length. Of chamber.	Length. Of rifling.	Length. Total of bore.	Maximum, exterior diameter.	Diameter at muzzle.	Rifling. No. of grooves.	Rifling. Width of grooves.	Rifling. Width of lands.	Rifling. Depth of grooves.	Rifling. Twist.	Preponderance.	Nature of gas-check.	Carriage. Nature.	Carriage. Material.	Carriage. Weight.	Carriage. Maximum elevation allowed by carriage.
			Inches.	Pounds.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches					Feet.					Pounds.	
*Prussian 21 c. m. B. L. mortar	Bronze	Double prismatic wedge.	8.238	6,655	80.31	17.36	48.70	66.06	21.63	13.38	30	0.5748	0.287	0.1	17.	...	Copper ring abutting against a steel bushing.	Is mounted on wheels and connected with a limber for transport. The necessary height of cheek is obtained by wooden trunnion brackets. Rests upon a wooden director or chassis.	Wood	4,457	75°
Russian 8-inch B. L. mortar	Steel-hooped	Cylindro-prismatic wedge.	8.00	7,202	89.98	26.182	44.016	70.198	25.	13.98	30	0.558	0.279	0.09	26.6	0	Steel ring	Is mounted on wheels and connected with a limber for transport. Same model as 6-inch mortar carriage, varying only in dimensions.	Wrought-iron	...	72°
Austrian 8-inch B. L. mortar	Cast-iron	Cylindro prismatic wedge.	8.238	10,241	80.89	26.38	33.77	60.15	30.	18.15	30	...	...	...	41.2	...	Ring of tambac with paste-board bottom.	Is mounted on wheels and connected with a limber for transport.	Wrought-iron	5,140	60°
†French 22 c. m. M. L. howitzer	Cast-iron, steel-hooped.	...	8.789	8,140	99.50	6.56	86.14	92.60	24.56	15.48	3	2.56	6.844	0.236	...	400	...	Old model	Wood	1,650	46°
English 8-inch M. L. howitzer	Wrought-iron, steel-tubed.	...	8.00	5,164	61.125	12.5	35.50	48.	25.	14.	4	1.5	4.778	0.18	10.6	220	...	Is mounted on wheels and connected with a limber for transport. A bed is proposed mounted on rollers with friction recoil check, and constructed of wrought iron. The carriage is similar to that of the 6.3-inch howitzer. (See Treatise on Military Carriage, 1877.)	Wrought-iron	4,802	40°
Krupp 21 c. m. B. L. howitzer	Steel-hooped	Cylindro-prismatic wedge.	8.268	6,660	97.05	...	...	80.	21.85	13.	50	0.36024	0.15748	0.059	24.115	0	Steel ring	Is mounted on wheels and connected with a limber for transport.	Wrought-iron	4,460	45°

* Bronze mortar, model of 1870, converted. † Converted smooth-bore howitzer.
The diameter of the trunnions of the above pieces is about the same as that of the bore.
For details of Italian 22 c. m. rifled howitzer, see *Revue D'Artillerie*, January, 1873.
For details of Spanish 21 c. m. rifled howitzer, see *Revue D'Artillerie*, January, 1873, and Februarry, 1878.

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V.—COMPARATIVE TABLE OF FIRE OF EUROPEAN 8-INCH RIFLED HOWITZERS AND MORTARS.

Piece.	Caliber.	Weight.	Length. Of bore.	Length. Of rifling.	Twist of rifling. Calibers.	Twist of rifling. Final inclination.	Charge. Kind.	Charge. Weight.	Projectile. System.	Projectile. Length.	Projectile. Weight, loaded.	Projectile. Bursting charge.	Ratio of— Weight of charge to weight of projectile.	Ratio of— Weight of projectile to weight of piece.	Initial velocity.	Elevation.	Pressure per square inch of bore.	Recoil.	Range.	Time of flight.	Deviation. Lateral.	Deviation. Longitudinal.	Derivation.	Remarks.
	Inches.	Tons.	Calibers.	Calibers.				Pounds.		Calibers.	Pounds.	Pounds.			Feet.			Feet.	Yards.	Seconds.	Yards.	Yards.	Yards.	
Prussian 21 c. m. B. L. mortar	8.268	2.9710	8.01	5.78	25	7	Ordinary cannon..	7.7	Lead coated .	2.5	176.0	11.0	1 to 23	1 to 38	704	45°	....	....	4,370	....	9.6	16.3	30.6	Shell 3 cals. long funnelled, and of 2⅔ cals. [illegible]. Larger charges than 7.7 lbs. proved too heavy for the piece.
Russian 8-inch B. L. mortar	8.00	2.2171	8.76	5.50	40	......	Large grain. ..	11.6	Lead coated .	2.5	175.83	6.08	1 to 15	1 to 41	751	....	10.657	....	....	....	....	....	....	With 17 lbs. prismatic powder the firing was wild.—*Revue D'Art.*, July, 1877.
Austrian, 8 pouces B. L. mortar	8.268	4.5719	7.30	4.08	60	3° 1' 16"	Ordinary cannon..	12.32	Lead coated .	2.5	191.4	8.8	1 to 13	1 to 53	....	45°	....	....	4,940	....	3.83	54.6	142.	This piece, after 1,144 rounds, showed but little diminution of accuracy.—*Revue D'Art.*, July, 1877.
French, 22 c. m. M. L. howitzer	8.789	3.6339	10.53	9.80	..	0° to 6°	Powder, Ripault ..	13.2	Studs	2.25	175.56	8.8	1 to 13	1 to 46	843	40°	....	....	5,707	32.1	15.6	86.	174.	
English, 8-inch M. L. howitzer.......	8.00	2.3053	6.00	4.438	16	11° 6' 31"	R. L. G.... ...	10.0	Studs	3.	180.0	14.52	1 to 18	1 to 29	....	40° 05'	....	....	4,931	30.1	9.6	33.7	265.	
Krupp 21 c. m. B. L. [illegible]	8.268	3	9.6	..	35	....	Prismatic, 7 holes. D = 1.64	16.	Copper bands	2.8	200.	10.5	1 to 12.5	1 to 33.3	....	....	....	....	....	....	....	....	....	
							Large grains. Grs., 0".24 to 0".39 D = 1.64.	6.6	....	2.8	200.	10.5	1 to 30.3	1 to 33.3	....	8° 30'	....	....	2,200	....	2.48	28.76	......	

REMARKS.—The French howitzer and the Austrian mortar of 8 pouces permit of the attainment of the greatest ranges, but their weights are very considerable; the Austrian mortar, particularly, appears to have an excessive weight relatively to the effects attainable with it. It is possible by the system of banding to reduce this weight say, at least 1,760 pounds, to give the piece [illegible] of bore, which would permit the use of larger charges and of a more progressive powder, by means of which ranges of 5,460 yards should be obtained. [illegible], however, it has above all a notable inferiority in point of accuracy of range. In the Russian 8-inch mortar, with 17 pounds prismatic powder, the pressure was 17,800 pounds, while in the 8-inch gun (light) with same charge, the pressure was only 15,560 pounds per square inch.—(*Revue D'Artillerie*, June, 1875.) The Prussian mortar (so far as we are able to judge [illegible]) has a sensible superiority over the Austrian mortar in point of accuracy of range, but in accuracy of direction on the centers the Austrian mortar is very much superior to the Prussian. This latter fact would tend to prove that the Prussians, notwithstanding the improvements made in their shell, have not yet succeeded in giving [illegible] as is possessed by the Austrian shell. In respect to this, however, it should be observed that the inclination of the rifling in the Prussian mortar is 7°, while in the Austrian mortar the inclination is only 3°. It is generally admitted in France that the inclination of the rifling for large pieces should but little exceed 4°. As the French 22 c. m. [illegible] with those of other countries, a new model has been prepared, of which the following are principal features: Caliber, 21 c. m.; material, cast iron, steel-hooped, or bronze; weight, 7,700 pounds; length of rifling 5 calibers; number of grooves, 24; twist, one turn in 30 calibers; system of breech mechanism, cylindro-prismatic wedge; [illegible] weight 176 pounds; weight of bursting charge, 11 pounds; gas check, copper or brass ring; carriage, of plate-iron; kind of powder, medium-sized grain, giving about 5,500 pounds pressure. Weight of carriage, 5,500 pounds.—(*Revue D'Artillerie*, June, 1874.) The French are now experimenting with a new rifled howitzer, the details of construction of which are not definitely known; the material is said to be steel. (1879.)

VI.—TABLE OF PRINCIPAL DIMENSIONS OF EUROPEAN 10 AND 11 INCH RIFLED HOWITZERS AND MORTARS.

Piece.	Material of piece.	System of breech mechanism.	Caliber of piece.	Weight.	Length. Nominal, exterior.	Length. Of chamber.	Length. Of rifling.	Length. Total of bore.	Diameter. Maximum, exterior.	Diameter. At muzzle.	Diameter. Over breech-band.	Diameter. Of trunnions.	Diameter. Of chamber.	Rifling. Number of grooves.	Rifling. Width of grooves.	Rifling. Width of lands.	Rifling. Depth of grooves.	Rifling. Twist.	Preponderance.	Nature of gas-check.	Carriage. Nature.	Carriage. Material.	Carriage. Weight.	Carriage. Maximum elevation allowed.
			Inches.	Pounds.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Feet.	Pounds.				Pounds.	
Krupp, 28 c. m. B. L. howitzer	Steel, hooped...	Cylindro-prismatic wedge.	11.023	22,000	125.98	31.295	67.716	99.012	35.43	18.50	39.37	12.0	11.41	72 (parallel.)	0.303	0.177	0.137	36.736 (uniform)	......	Steel ring ..	Top carriage and chassis, hydraulic buffer.	Wrought iron	20,[illegible]84	75°
			11.023	...	......	15.5	....	99.012	....	....	....	....	11.26	64										
Russian, 11-inch B. L. mortar..........	Steel, hooped..	Cylindro-prismatic wedge.	11.00	....	128.20	36.00	64.20	100.20	36.00	19.60	39.20	12.0	13.39	36 (cuneiform.)	0.64	0.32	0.135	....	......	Steel ring...	Top carriage and chassis, with hydraulic buffer.	Wrought iron	....	....
*English, 10-inch M. L. howitzer	Wrought-iron, steel-tubed.	....	10.00	13,440	77.50	10.00	50.00	60.00	34.50	18.25	....	10.00	....	7	1.50	2.988	0.2	10.66	......	....	†Top carriage and chassis, hydraulic buffer.	Wrought iron.	18,900	40°

REMARKS.—* Experimental—not adopted. † Proposed carriage.

VII.—COMPARATIVE TABLE OF FIRE OF EUROPEAN 10 AND 11 INCH RIFLED HOWITZERS AND MORTARS.

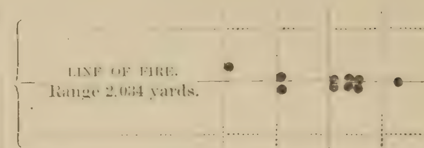
Piece.	Caliber.	Weight.	Approximate length. Of bore.	Approximate length. Of rifling.	Twist of rifling. Calibers.	Twist of rifling. Final inclination.	Charge. Kind.	Charge. Weight.	Projectile. System.	Projectile. Length.	Projectile. Weight loaded.	Projectile. Bursting charge.	Ratio of— Weight of charge to weight of projectile.	Ratio of— Weight of projectile to weight of piece.	Initial velocity.	Elevation.	Pressure per square inch of bore.	Recoil.	Range.	Time of flight.	Rectangle containing all the shots. Length.	Rectangle containing all the shots. Width.	Mean difference in— Range.	Mean difference in— Deflection.	Mean reduced deflection.	Derivation.
	Inches.	Tons.	Caliber.	Caliber.				Pounds.		Caliber.	Pounds.	Pounds.			Feet.			Feet.	Yards.	Seconds.	Yards.	Yards.	Yards.	Yards.	Yards.	Yards.
Krupp, 28 c. m. B. L. howitzer	11.023	9.82	9.	6.	40	....	Prismatic, d= 1.62 to 1.66, 7 holes.	44.	Lead coated	2½	437	25	1 to 10	1 to 50	1,030	5° 30'	....	....	2,115	....	56.	22.	....	....	....	....
																*22° 30'	....	....	6,349	....	47.	15.	....	....	....	....
																†60°	....	....	6,864	....	120.	38.	....	....	....	....
Russian, 11-inch B. L. mortar..............	11.023	10	9.	....	35	....	....	41.8	Copper bands...	....	....	....	....	....	1,016	45°	....	....	....	....	145.4	23.5	....	....	....	....
	11.	....	9.	5.83	....										1,050											
English, 10-inch M. L. howitzer	10.	6	6.	5.	13	....	R. L. G.	20.	Studs	3	360	24	1 to 18	1 to 37	....	40° 06'	....	....	‡4,816	....	....	....	68.5	350.2	10.26	....

REMARKS.—* Under this angle the projectile on striking the ground—a stony and sandy soil—plowed a furrow from 10 to 13 feet in length, with a maximum depth of 5 feet.
† Under this angle the projectile penetrated from 10 to 13 feet into the ground; the point of the projectile being turned to the front.—*Revue D'Artillerie*, September, 1875.

‡ The weight of the projectile in this case was 355 pounds.

VIII.—*Table showing comparative practice with rifled howitzers and S. B. mortars.*

Nature of piece.	Weight in cwts.	Caliber in inches.	Length— Of piece in inches.	Length— Of bore in inches.	Charge in pounds.	Weight of projectiles.	Bursting charge.	Elevation.	Range, yards.	Deviation in yards. Lateral.	Deviation in yards. In range.	Remarks.
English.						*Pounds.*	*Pounds.*	°				
13-inch mortar	100	13	53	39	10	204	11	15	2,930	55	62	This table does not give the results with the service 8-inch R. M. L. howitzer, but only the experimental practice, through the results of which we can compare S. B. mortars and rifled howitzers generally when firing about same charges.
9-inch howitzer	76.2	9	76	54	10	200	7	39	4,742	10	23	
10-inch mortar	52	10	46	35	4.75	95	5.25	45	2,720	100	78	
8-inch howitzer	64	8	65.9	48	6	120	5.75	39	4,534	20	57	
American.												Fire of Prussian 21 c. m. B. L. rifled mortar.
13-inch S. B. mortar	152.85	13	56.5	35.1	*10	216	7	45	3,187	....	....	
					20				4,636			
10-inch S. B. mortar	65.17	10	49.25	32.5	7.5	101.67	2	45	3,471	....	....	
					12				4,536	....	....	



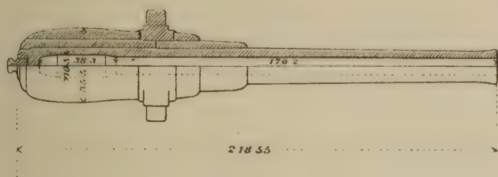
*Initial velocity, 761 feet.

HEAVY RIFLED GUNS.

ENGLAND.

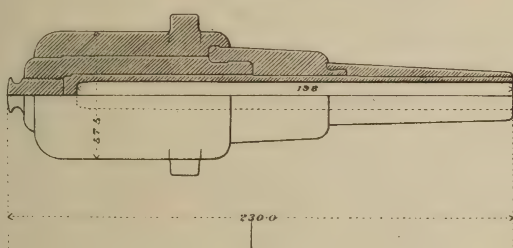
8 INCH. (Armstrong)

(11 Tons)



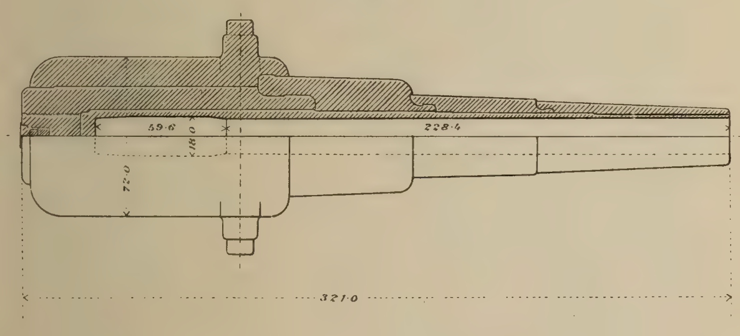
12·5 INCH.

(38 Tons)

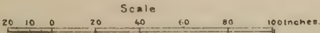


16 INCH.

(80 Tons)



Scale

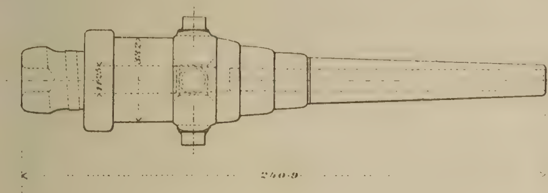


HEAVY RIFLED GUNS.

KRUPP'S WORKS.

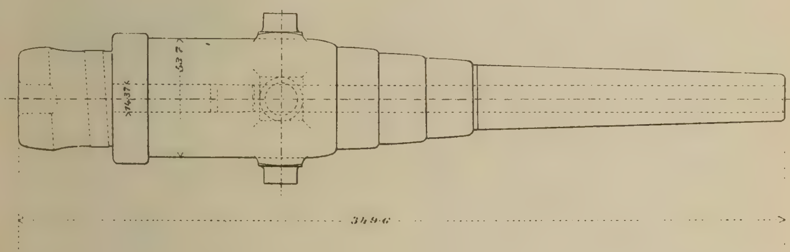
9·45 INCH.

(18 Tons)



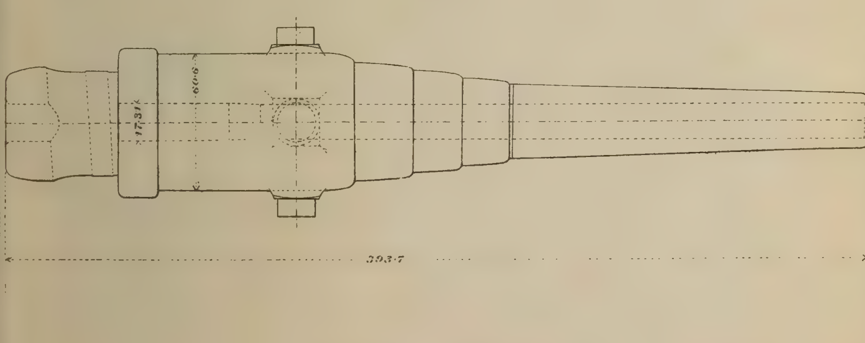
13·97 INCH.

(51 Tons)



15·75 INCH.

(72 Tons)



Scale.

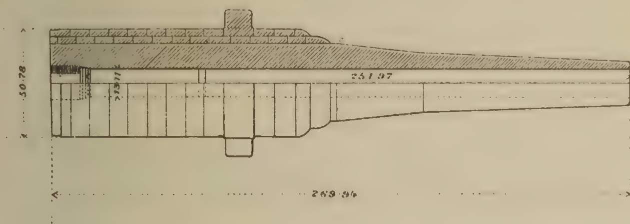
20 10 0 40 60 80 100 Inches.

HEAVY RIFLED GUNS.

ITALY.

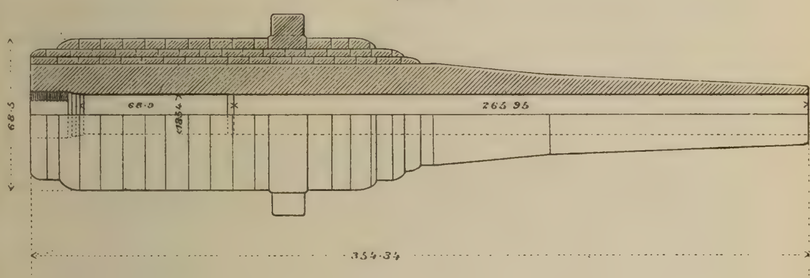
12·6 INCH.

(38 Tons)



18·1 INCH.

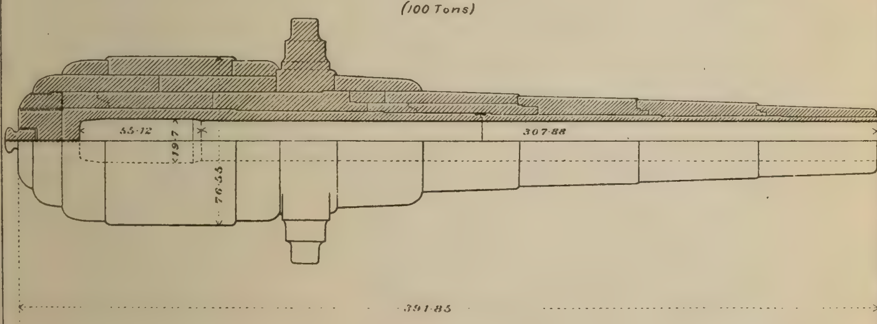
(87 Tons)



17·7 INCH.

(Armstrong)

(100 Tons)



Scale

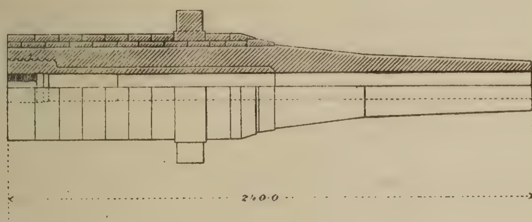
20 10 0 20 40 60 80 100 Inches

Appendix 26—1880.

HEAVY RIFLED GUNS.

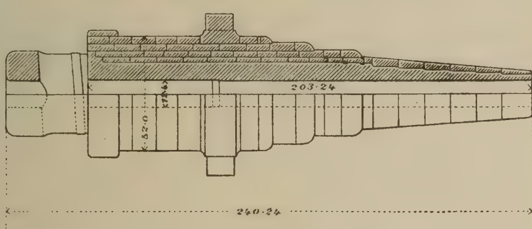
FRENCH 12·6 INCH.

(34 Tons)



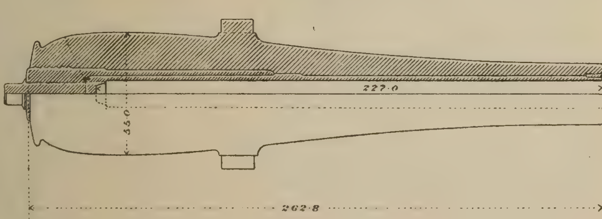
RUSSIAN 12 INCH.

(39 Tons)



AMERICAN 12·25 INCH.

(45 Tons.)



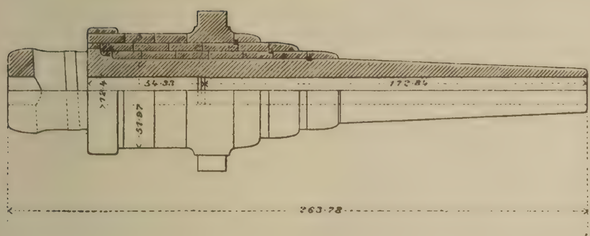
Scale.

HEAVY RIFLED GUNS.

KRUPP 12 INCH.

(Probable Construction)

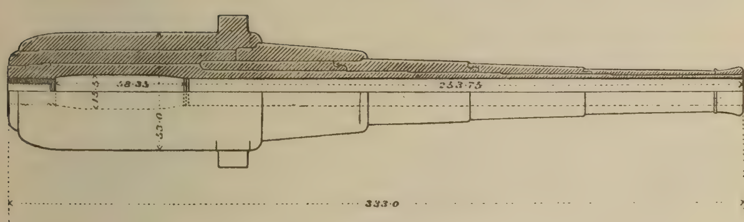
(36 Tons)



ENGLISH 12 INCH.

(Proposed Model)

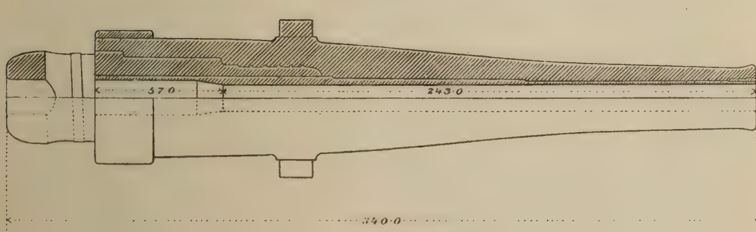
(42 Tons)



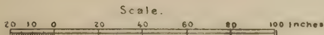
AMERICAN 12 INCH.

(Proposed Model.)

(55 Tons.)



Scale.

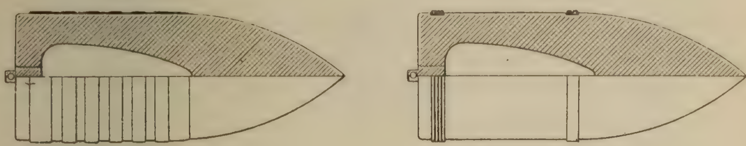


PROJECTILES FOR HEAVY RIFLED GUNS.

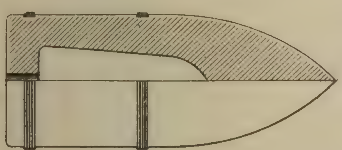
(CORED SHOT)

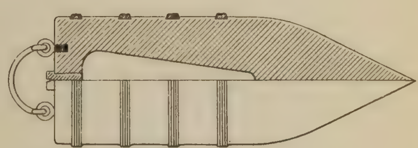
KRUPP.

Old Model. *New Model.*



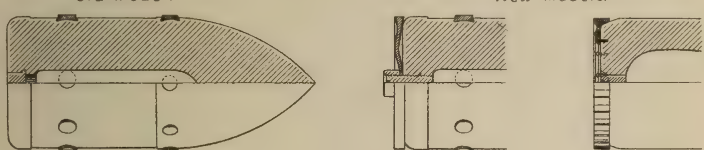
FRENCH. ITALIAN.



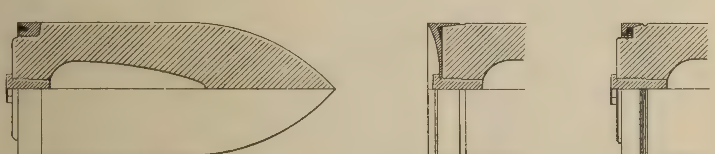


ENGLISH.

Old Model. *New Models.*



AMERICAN.

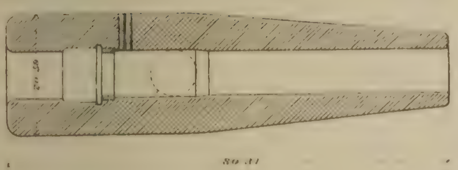


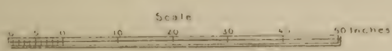
Appendix 26—1880.

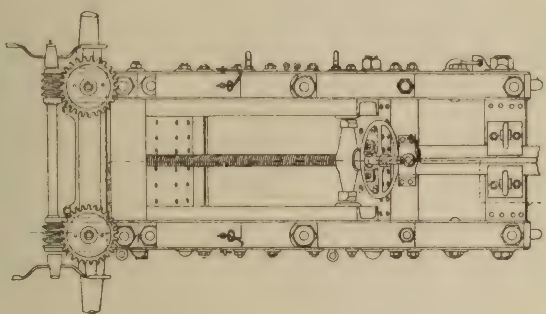
RIFLED HOWITZERS AND MORTARS.

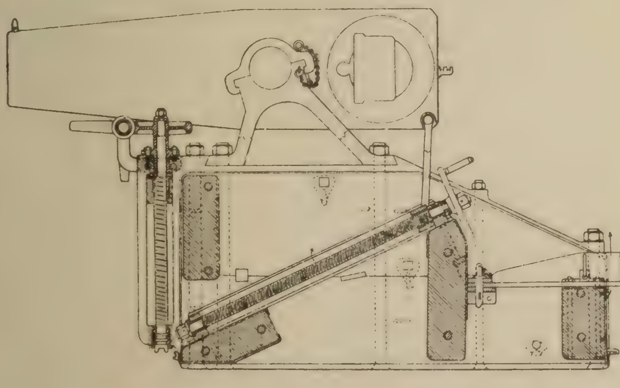
GERMANY.

8 INCH.





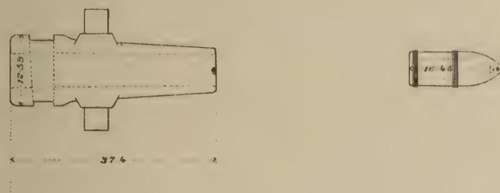




RIFLED HOWITZERS AND MORTARS.

KRUPP'S WORKS.

5·9 INCH.



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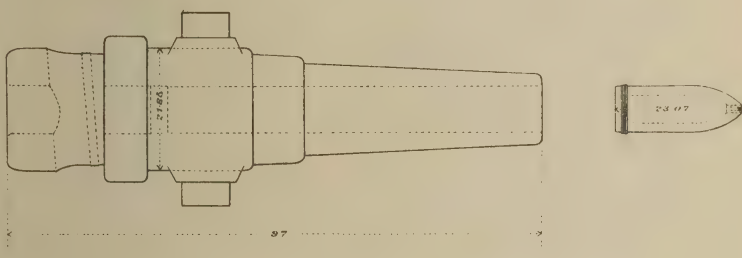
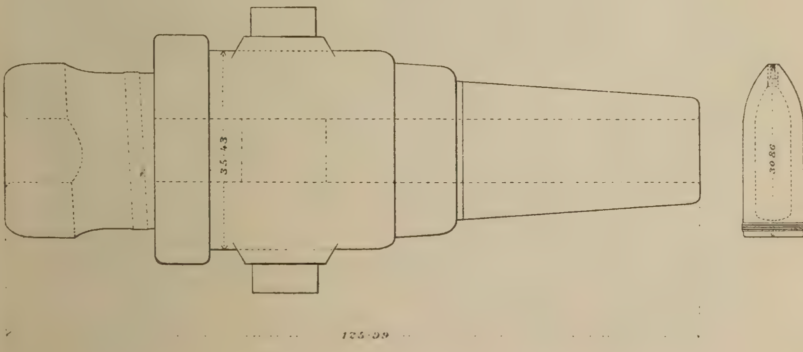


11 INCH.

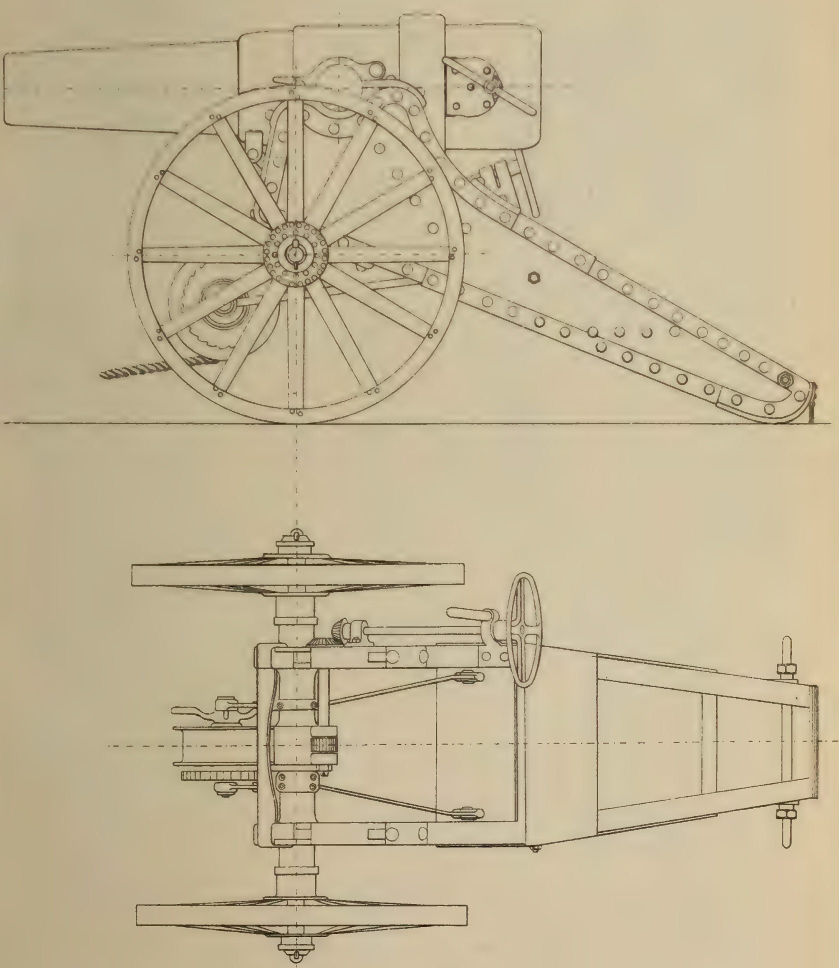


Scale.
10 5 0 10 20 30 40 50 Inches

RIFLED HOWITZERS AND MORTARS.

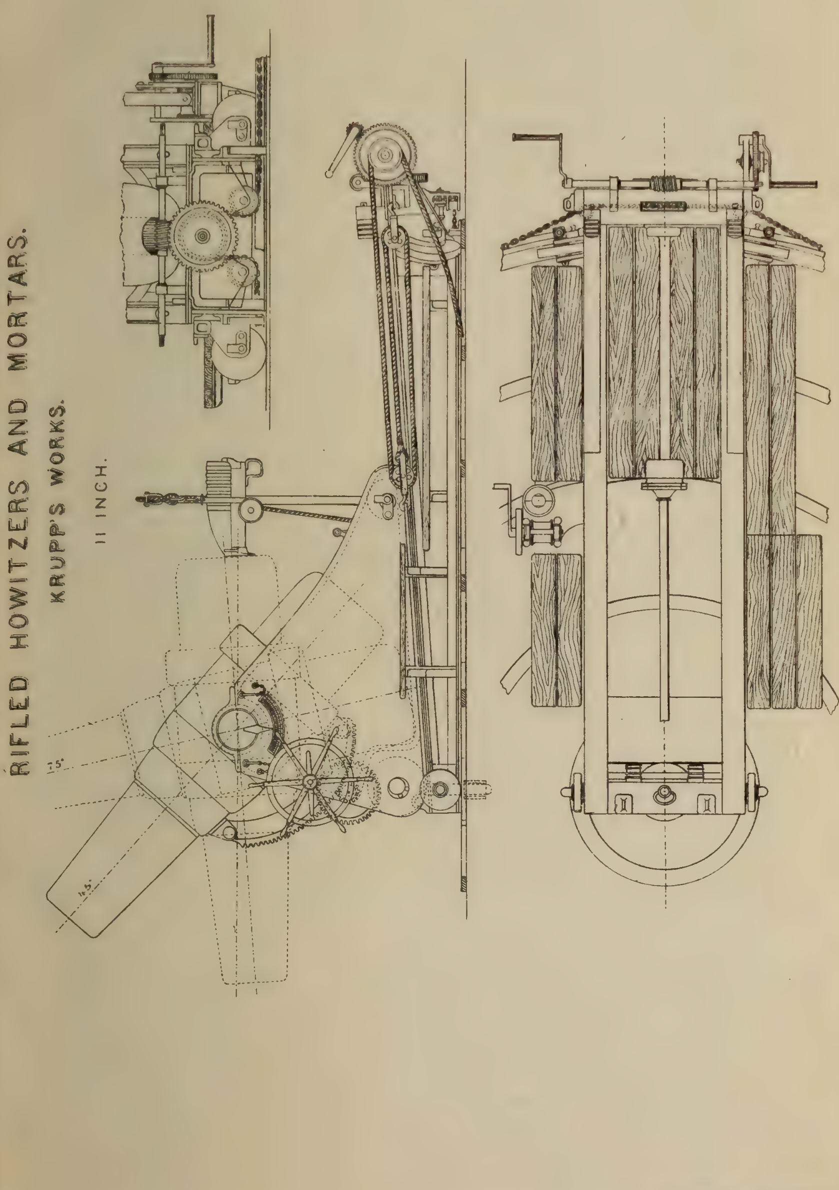
KRUPP'S WORKS.

8·26 INCH.



Scale.

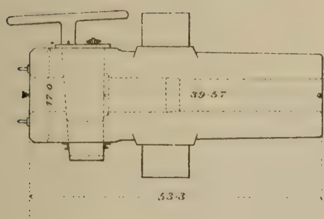
10 5 0 10 20 30 40 50 Inches.


RIFLED HOWITZERS AND MORTARS.
KRUPP'S WORKS.
11 INCH.

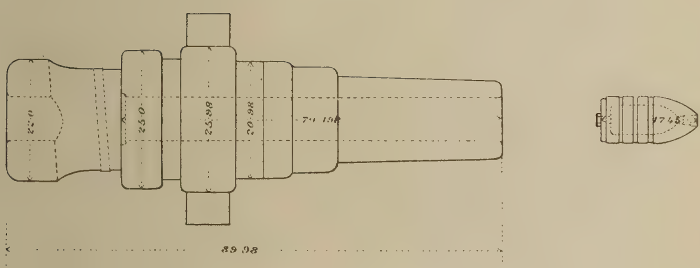
RIFLED HOWITZERS AND MORTARS.

RUSSIA.

6 INCH.



8 INCH.



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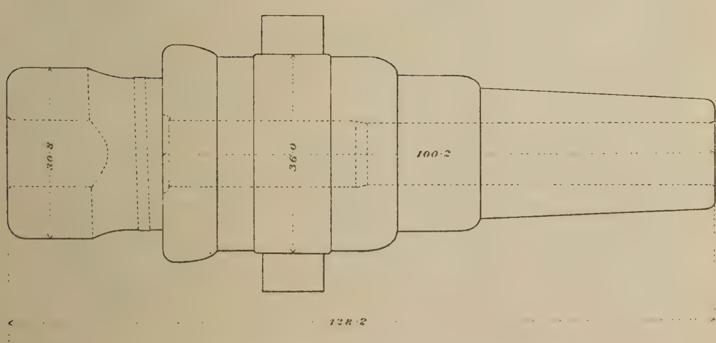
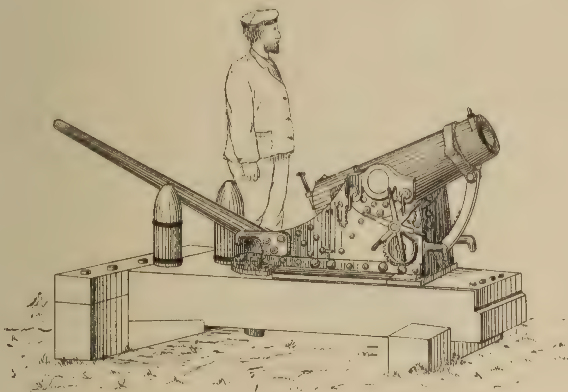


Scale
10 5 0 10 20 30 40 50 Inches.

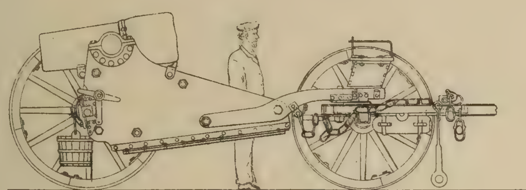
Appendix 26—1880.

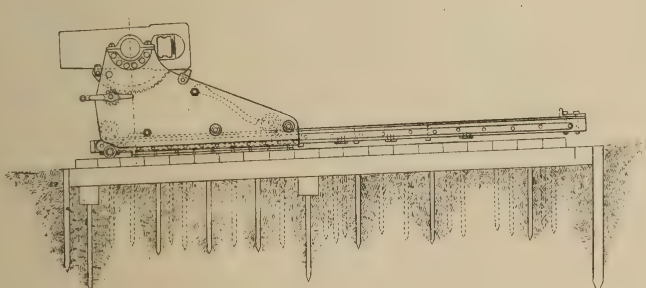
RIFLED HOWITZERS AND MORTARS.

5·9 INCH. KRUPP.



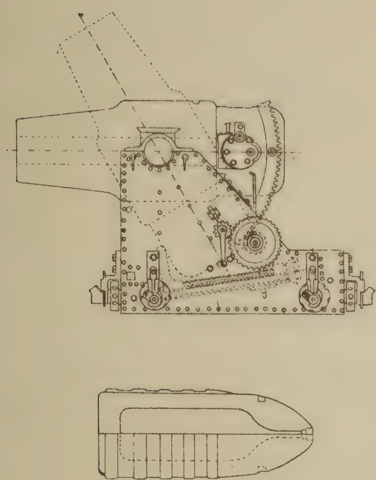
6 INCH. RUSSIAN.



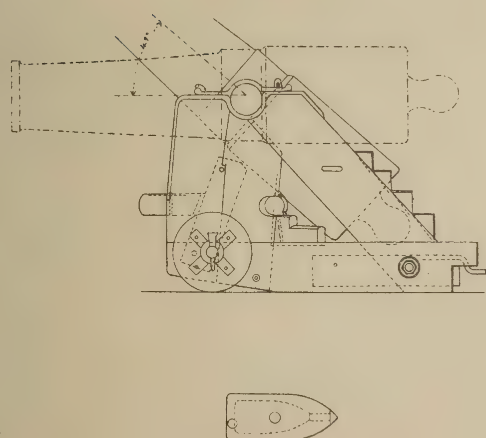


RIFLED HOWITZERS AND MORTARS.

AUSTRIAN 8 INCH.



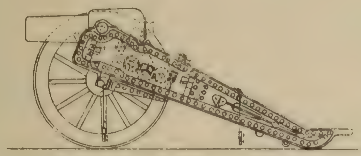
FRENCH 8·6 INCH.



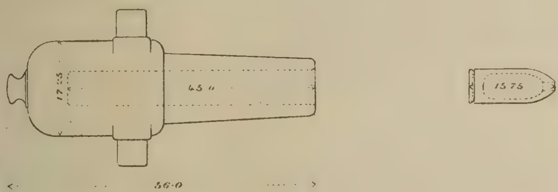
RIFLED HOWITZERS AND MORTARS.

ENGLAND.

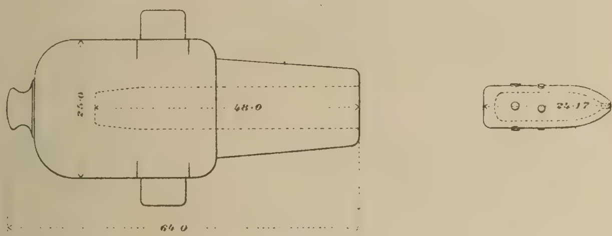
6·3 INCH



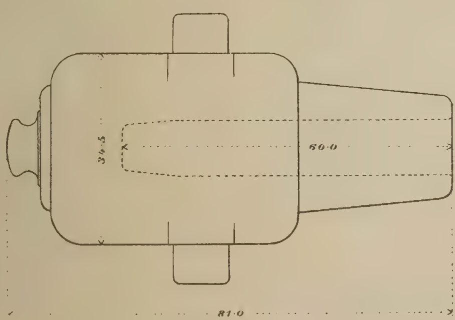
6·3 INCH.



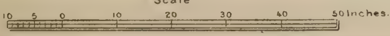
8. INCH.



10 INCH.



Scale



APPENDIX 27.

SHOWING STATIONS AND DUTIES OF THE OFFICERS OF THE ORDNANCE DEPARTMENT ON THE 1st OF OCTOBER, 1880.

Rank and name.	Duty.
BRIGADIER-GENERAL.	
Stephen V. Benét	Chief of Ordnance.
COLONELS.	
1. P. V. Hagner, brevet brigadier-general	Commanding the Watervliet Arsenal.
2. T. T. S. Laidley, brevet	Commanding the Watertown Arsenal.
3. J. G. Benton, brevet	Commanding the National Armory.
LIEUTENANT-COLONELS.	
1. J. McAllister, brevet colonel	Commanding the Benicia Arsenal.
2. S. Crispin, brevet colonel	Commanding the Ordnance Agency; President of the Ordnance Board, and Constructor of Ordnance.
3. T. G. Baylor, brevet colonel	Commanding the New York Arsenal, and member of the Ordnance Board.
4. J. M. Whittemore	On duty in the office of the Chief of Ordnance, and in temporary command of the Washington Arsenal.
MAJORS.	
1. A. R. Buffington, brevet	Commanding the Allegheny Arsenal,
2. D. W. Flagler, brevet lieutenant-colonel	Commanding the Rock Island Arsenal.
3. A. Mordecai, brevet lieutenant-colonel	Instructor of Ordnance and Gunnery, United States Military Academy.
4. S. C. Lyford, brevet lieutenant colonel	Commanding the Frankford Arsenal.
5. F. H. Parker, brevet	Commanding the Piccatinny Powder Depot.
6. J. P. Farley	Commanding the Kennebec Arsenal.
7. L. S. Babbitt	Commanding the Fort Monroe Arsenal.
8. W. A. Marye	Commanding the Augusta Arsenal.
9. I. Arnold, jr	Commanding the Indianapolis Arsenal.
10. C. Comly	Member of the Ordnance Board.
CAPTAINS.	
1. J. H. Rollins, brevet	On sick leave of absence.
2. J. R. McGinness, brevet major	Commanding the Saint Louis Powder Depot.
3. G. W. McKee, brevet major	Assistant, Rock Island Arsenal.
4. F. H. Phipps, brevet	Commanding the San Antonio Arsenal, and Chief Ordnance Officer Department of Texas.
5. J. W. Reilly, brevet	Assistant, Watervliet Arsenal.
6. J. A. Kress, brevet major	Commanding the Vancouver Arsenal, and Chief Ordnance Officer Department of the Columbia.
7. O. E. Michaelis, brevet	Assistant, Frankford Arsenal.
8. W. Prince, brevet	On sick leave of absence.
9. C. E. Dutton	On duty under the Interior Department.
10. J. G. Butler	Assistant, Watertown Arsenal.
11. C. Bryant	Assistant to the Constructor of Ordnance.
12. A. L. Varney	Assistant, Watervliet Arsenal.
13. J. C. Clifford	Assistant, Watervliet Arsenal.
14. J. E. Greer	Assistant, National Armory.
15. J. Pitman	Assistant, Watertown Arsenal (on duty under the Interior Department).
16. C. Shaler	Chief Ordnance Officer Department of the South.
17. H. Metcalfe	Assistant, Frankford Arsenal, and Inspector of Contract Ammunition.
18. W. S. Starring	Assistant to the Constructor of Ordnance.
19. C. S. Smith	Assistant, Ordnance Agency.
20. S. E. Blunt	Chief Ordnance Officer Department of Dakota.
FIRST LIEUTENANTS.	
1. F. Heath	Commanding the Cheyenne Ordnance Depot.
2. D. M. Taylor	Chief Ordnance Officer Department of the Missouri, and commanding the Fort Leavenworth Ordnance Depot.
3. D. A. Lyle	Assistant, National Armory, and member of the Board on Life-saving Apparatus, &c., under the Secretary of the Treasury.
4. J. Rockwell, jr	Assistant Instructor of Ordnance and Gunnery, Military Academy.
5. J. C. Ayres	Commanding the Fort Abraham Lincoln Ordnance Depot.

Showing stations and duties of the officers of the Ordnance Department, &c.—Continued.

Rank and name.	Duty.
6. M. W. Lyon	Assistant, Benicia Arsenal.
7. C. W. Whipple	Assistant to the Constructor of Ordnance.
8. A. H. Russell	Assistant, Watertown Arsenal.
9. R. Birnie, jr.	Assistant, National Armory.
10. I. MacNutt	Assistant, Rock Island Arsenal.
11. C. C. Morrison	Assistant, National Armory.
12. F. Baker	Assistant, Rock Island Arsenal.
13. O. B. Mitcham	Acting Assistant Professor of the French Language and English Studies.
14. H. D. Borup	Assistant, Frankford Arsenal.
15. L. L. Bruff	Assistant, Rock Island Arsenal.
16. C. H. Clark	Assistant to the Instructor of Ordnance and Gunnery, United States Military Academy.
ORDNANCE STOREKEEPERS.	
E. Ingersoll, major	On duty, National Armory.
W. R. Shoemaker, captain	Commanding the Fort Union Arsenal.
B. H. Gilbreth, captain	On sick leave of absence.
E. D. Ellsworth, captain	On sick leave of absence.
W. Adams, captain	On duty, Fort Monroe Arsenal.
A. S. M. Morgan, captain	On duty, Allegheny Arsenal.
W. H. Rexford, captain	On duty, Benicia Arsenal.
F. Whyte, captain	On sick leave of absence.
D. J. Young, captain	On duty, Watervliet Arsenal.
M. J. Grealish, captain	On duty, Augusta Arsenal.

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